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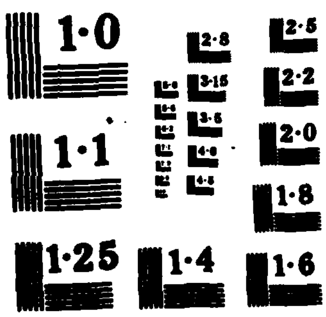
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STRUCTURES TECHNICAL MEMORANDUM 400

FLUTTER CLEARANCE TESTS ON A TRANSAVIA PL-12/T-400 SKYFARMER

by

A. GOLDMAN and S. GALEA

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FLUTTER CLEARANCE TESTS ON A TRANSAVIA PL-12/T-400 SKYFARMER

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SUMMARY

A ground resonance test and subsequent flight tests have been conducted on a Transavia T-400 Skyfarmer. The natural modes and frequencies of vibration were measured in the ground tests, and monitored during flight tests in which attempts were made to induce flutter. The results of these tests are presented.

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1. INTRODUCTION

The Transavia T-400 Skyfarmer is the latest version of the twin-boom agricultural aircraft and incorporates several changes from the T-300 model previously tested (Ref 1). The changes which could affect the flutter characteristics are ~~as follows:~~

a) Change of engine from 6 cylinder 300 horsepower to 8 cylinder 400 horsepower;

b) Increase in length of tail booms by 750 millimetres;

c) Increase in stub-wing span by 900 millimetres;

d) Removal of the spring-tab from the elevators; and

e) Addition of a dorsal stabiliser fin along each tail boom.

In order to ascertain the effect these changes have made to the structural modes and frequencies, the aircraft was subjected to a ground resonance test. Because the changes were expected to bring about a lowering of the boom bending frequencies, an improved low frequency support system was required for this test. By using a partially inflated tube under each main wheel, and a rubber cord suspending the nose, the rigid body modes of pitch, roll, and heave were 0.4 hertz, 1.1 hertz and 2.2 hertz respectively.

The aircraft supplied for the ground resonance test was also used for the later flight tests but initially it was fitted with a 6 cylinder engine. An additional mass of 75 kilogrammes was added to the engine to simulate the 8 cylinder engine. The aircraft was otherwise complete and serviceable, with 50 percent fuel on board and the hopper empty. The modification of the dorsal stabiliser fin was not included on the aircraft for the ground resonance test. Details of the aircraft are provided in Table 1 and the major dimensions are shown on Fig. 1(a).

2. TEST EQUIPMENT AND PROCEDURES

2.1 Ground Resonance Test

A maximum of ten electro-magnetic vibrators was used for these tests. These vibrators were nominally identical having a maximum thrust of 138 newtons. The vibrators were attached to the structure, using lightweight pushrods, at the extremities of the wing front spar and trailing edge, the starboard front spar and port rear-spar of each tailplane, in a horizontal direction at the lowest point of the port fin, along the port boom, and at the tips of the stub wings. Not all locations were used at the same time, relocation being necessary for the boom and horizontal measurements. The control surfaces were clamped for all structural modes except the boom bending mode at 17.8 hertz, when the port elevator was released to investigate the mass-balance properties in this mode. Control surface modes were measured with the aircraft structure propped on stands. The tuning and measurement of modes was carried out using 16 accelerometers, multi-channel filters, a resolved component ratiometer, Lissajous figures, and a frequency response analyser. The details of the method are fully explained in Ref. 1. The locations of measuring stations are shown in Fig. 1(b) and Table 2 provides the dimensional locations of the measuring stations. In order to establish the range of frequencies within which the resonant modes occurred, random noise was applied at several locations with the response being fed into a FFT spectrum analyser. Figures 2 to 6 show these responses which were used as starting points for tuning individual modes.

As was expected, many modes were unchanged from the T-300 aircraft, and these modes were tuned, identified, but not measured in detail. They are listed in Table 3 but not plotted. The modes of different frequency are presented in Figs. 8 to 15. The mode at 17.8 hertz caused some concern as it appeared that the elevator mass-balance would operate to amplify the flutter mode rather than attenuate it. This mode had not been measured on the T-300 aircraft in previous tests. A brief test on an available T-300 aircraft established that this mode occurs on that aircraft at 21.5 hertz, as shown in Fig. 7. The mode was measured along the boom and tailplane to establish that it had the same adverse mass-balance characteristics. This mode had not been detected in previous tests because the vibrators had been placed too close to the node, which occurs at the junction of the boom and fin post.

2.2 Flight Tests

As there did not appear to be any modes which were likely to couple to produce flutter, other than the 2-node boom bending with elevator rotation which had not been a problem on the T-300 at speeds up to 175 knots, the aircraft was permitted to fly up to 110 knots based on simple proportionality of frequencies and speeds compared to the T-300 aircraft. For the first flight, and subsequent flying at speeds up to 110 knots, a two-channel tape recorder was installed in the aircraft to record the accelerometer outputs at locations along the starboard boom and on the elevator of the starboard tail. Several flights were made to obtain data at 5 locations along the boom at air speeds of 60, 80, and 110 knots and at 2000 RPM and 2600 RPM engine speeds. The data recorded were analysed on a FFT spectrum analyser and Figs. 16 and 17 show these spectra for the same location at several speeds. It will be seen that a sharp peak occurs at engine speed and at half engine speed, and at 110 knots there is some indication of the mode on the boom at 17.8 hertz. These initial flights were made to investigate this particular mode, and to establish that the engine did excite the aircraft structure at half engine speed. This, together with the test carried out on the T-300 tailboom explains the 21.5 hertz vibration observed during the T-300 flight tests reported in Ref. 1.

For the flutter clearance flights, two 4-track tape recorders were installed in the aircraft to record accelerometer outputs from the locations listed in Table 4. In Table 5 the flights are listed with the speeds flown in each flight. Prior to these flights, the aircraft was modified by the addition of the dorsal stabiliser fin having a deep inverted U section increasing in depth towards the tail.

At each speed, the pilot activated the elevators and ailerons with sharp raps in both directions. He then maintained speed for at least one minute to record response to the ambient turbulence, and then reduced engine speed whilst maintaining air speed to establish whether any modes were being excited by the engine vibrations and not by aerodynamic forces.

The recorded data were analysed on a 4-channel FFT spectrum analyser to establish the frequency content at each location due to turbulence input. Figures 22 to 37 show these spectra for each air speed. Between flights, the means of assessing damping were limited to observations of the peaks on the frequency spectra, and the random decrement signatures produced by a portable microprocessor. These showed sufficient damping in each mode to permit progress to the next speed. The mode at 22 hertz was hard to separate from the engine induced vibration so, for flights 5, 6, and 7, the engine speed was reduced to 2300 RPM. This will be easily observed on

Figs. 34 to 37. Flight 7 was flown to record better data of the response to stick raps at three lower speeds.

The flight test records were replayed later, through analogue filters, into a signal processor coupled to a digital computer in order to obtain the random decrement signatures shown in Figs. 38 to 42. The process for obtaining these signatures is fully explained in Ref. 2. The subsequent analysis to extract the frequencies and dampings used a curve-fitting programme. The analyses on Figs. 38 to 42 are the results of the best fits for each random decrement signature.

3. TEST RESULTS

3.1 General

The vibration mode shapes and corresponding frequencies of all measured and identified flexible modes are listed in Table 3. For comparison purposes the frequencies of the corresponding modes of the T-300 aircraft are also listed. Those modes which were measured in some detail have been plotted and are presented in Figs. 8 to 15. For clarity of presentation, not every measured point is plotted, and in cases where the vibration amplitudes of certain components of the aircraft structure were negligible, measurements were not recorded. The modes which have frequencies corresponding to frequencies measured on the T-300, and which are essentially modes involving only the parts of the structure which are identical with the T-300, were tuned using Lissajous figures and the resolved component ratiometer to identify the mode and its resonant frequency, but not measured.

3.2 Details of Mode Shapes

Mode at 3.8 Hz. (Fig 8) -

This mode is the symmetric lateral boom bending mode and could be excited quite readily using a single shaker on the port fin.

Mode at 4.4 Hz. (Fig 9) -

This is the antisymmetric lateral boom bending mode and was equally easily excited using the single shaker input.

Mode at 4.8 Hz. (Fig 10) -

This is the antisymmetric vertical boom bending mode. The motion of the wing and stub wing is essentially rigid-body motion.

Mode at 6.7 Hz. (Fig 11) -

This is the symmetric vertical boom bending mode with a pitching motion of the wing and fuselage.

Mode at 9.23 Hz. (Fig 12) -

This is the symmetric torsion mode of the tail booms. Because of the mass of the tail plane assembly, some bending of the boom and fin appears in this mode.

Mode at 9.43 Hz. (Fig 13) -

This is the antisymmetric torsion mode of the tail booms, and a similar boom bending to the previous mode is apparent.

Mode at 17.8 Hz. (Fig 14) -

This mode is a 2-node vertical bending mode of the tail boom. Each boom had slightly differing frequencies and the frequency of 17.8 hertz was the best that could be achieved with the use of two vibrators, one on each boom. The initial measurement was made with the control surfaces clamped. This indicated a nodal line between the tailplane-elevator hinge and the elevator balance mass. A further measurement, with the control surfaces free, confirmed that for this mode the static balance is incorrect. Figure 14(b) shows the mode shape along the boom with control surface clamped and free.

Mode at 29.95 Hz. (Fig 15) -

This is the stub-wing symmetric bending mode. The additional span has caused very little change to the frequency of this mode, mainly because the extension is of a light aluminium construction.

3.3 Flight Tests

In all the frequency spectra presented, the vertical axes are scaled in units of "g" r.m.s., "g" being the acceleration due to gravity (9.81 metres/sec/sec). The spectra are the result of averaging several sequential time histories using a 50 percent overlap and a Hanning window. The spectra have 400 frequency points providing a resolution of 0.125 hertz.

During the preliminary tests, response to turbulence was recorded from a location on the starboard boom and on the elevator. Several records were taken at different engine speeds and air speeds with the boom location being changed for each flight. In Figs. 16 and 17 it will be seen that the predominant peak at each speed and location occurs at a frequency corresponding to half the engine rotation speed. A peak may also be seen at full engine speed and, on Fig. 16, a further peak at 1.5 times engine speed. There are indications also that the vertical bending modes of the boom, measured on the ground at 4.8 hertz and 6.7 hertz, are well excited at these airspeeds. They appear as peaks at approximately 4 and 6 hertz on the elevator response spectra. On Fig. 17 the spectrum for the boom at 110 knots indicates a slight growth in the mode at 17.8 hertz.

Following these initial flights it was agreed to proceed with the flutter clearance flights which took place in November 1984 with the 400 horsepower engine installed, and a longitudinal dorsal stabilising fin fitted along the top of each boom. The first of this series of flights was flown to determine the critical engine speed for excitation of the mode at 17.8 hertz. This flight showed that the addition of the dorsal fin had increased the boom stiffness and raised the frequency of this mode to approximately 22 hertz, which is higher than half of the maximum engine speed of 2600 RPM.

Figures 22 to 37 present the spectra of the responses to turbulence at the eight locations for each speed from 90 to 162 knots. On Figs. 22 and 24 a large peak appears on the Stbd. boom response at 15 hertz and 24 hertz. As this was not apparent on the Port Boom, the location of the accelerometer was checked and found to be too close to the control system cables. There appear to be resonances in the control cables at these two frequencies. For the next flight the accelerometer was relocated in the same region between the control cables. For flights 6 and 7 the accelerometers on the two booms were repositioned on the underside of the booms, well clear of all control cables.

Responses to stick raps are presented in Figs. 18 to 21, which are 15-second time histories of data passed through a 15 hertz low-pass filter to remove the engine vibration and higher frequency noise. The response of the wing and tailplane to impulses on aileron and elevator may clearly be seen up to 150 knots. At 150 knots and above, the increased turbulence tends to swamp the impulse which, because of the preload required on the control column to maintain the dive angle, tends to be less effective. However, impulses can be seen on both control surfaces, and the corresponding responses of the main surfaces have satisfactory decay characteristics at all speeds.

Figures 38 to 42 show the random decrement signatures of four locations at varying air speeds and filter settings. Figure 38 indicates that the damping of the lateral boom bending mode was greater than 5 percent of critical damping at all speeds flown. The reduction in damping from 120 knots to 140 knots and the subsequent increase in damping at 162 knots may be due to non-linearities in the structure and differing levels of turbulence in the flights. It may also be a characteristic of the aeroelastic properties of the structure, but without flutter calculations this cannot be said with any certainty. Figure 39 was produced to measure the damping of the boom torsion modes in the region of 9 hertz. The other two modes included are leakage through the filters which have a 3 dB per octave roll-off characteristic and, although affecting the shape of the curve, cannot be accepted as a measure of any mode. Figure 40 provides the damping for the vertical boom bending mode at 4.8 hertz, which is seen to be increasing with air speed. Figure 41 provides the damping of the two wing bending modes, measured on the ground at 11.4 and 14.4 hertz. Both modes show sufficient damping at all speeds flown. Figure 42 shows the problem of having the engine speed close to twice the frequency of the structural mode under investigation. The first of the two frequencies in each pair is the 2-node boom bending mode at 22 hertz. The second, almost zero damped oscillation, is the engine induced vibration at 20.96 hertz corresponding to 2500 RPM, and 19.36 hertz corresponding to 2300 RPM. The bending mode has damping of 4.3 percent of critical damping at the maximum speed flown, which is quite satisfactory. However, the reduction in damping is quite rapid from 120 knots onwards as may be observed on the frequency spectra in Figs. 28, 30, 32, 34 and 36, where the amplitude of this mode is seen to rise quite markedly.

4. CONCLUSION

The T-400 Skyfarmer has been ground tested, in relation to its airframe vibration characteristics, and all the variations from the previous T-300 model measured in detail. The flight tests have been carried out and every reasonable effort made to induce flutter at speeds up to 162 knots. The aircraft, in the configuration tested, has been found to be clear of flutter at air speeds up to and including 162 knots.

REFERENCES

1. Goldman, A. : Flutter substantiation tests on Transavia PL-12/T-300 Airtruk,
ARL Structures Tech. Memo. 341
June 1982

2. Cox, P.M. : An assembly language program for calculating random decrement signatures.
ARL Structures Tech. Memo. 369
December 1983

TABLE 1(a)

Details of Aircraft for Ground Resonance Test

Type:	PL12/T400 Skyfarmer
Serial No.:	H 1107
Registration:	VH - BOU
Engine:	Lycoming Type IO-540-K1AS
Propellor:	Hartzell 3 bladed
Total Mass Approx:	1200 kilograms
Control Surface Balances:	
Elevator -	0.14 kilograms L.E. heavy
Aileron -	1.59 kilograms T.E. heavy
Rudder -	0.75 kilograms T.E. heavy

TABLE 1(b)

Changes for Flutter Clearance Flights

Engine:	Lycoming Type IO-720-D1BD
Total Mass Approx:	1430 kilograms (full fuel at take-off)
Max Permitted Mass:	2000 kilograms
Centre of Gravity at take-off:	0.476 metres aft of datum
Limits of Centre of Gravity:	0.410 to 0.590 metres aft of datum
Modification:	Introduction of a dorsal stabiliser fin along top of each boom

TABLE 2(a)

LOCATION OF WING MEASURING STATIONS

η \ ξ	0.015	0.202	0.635	0.765	0.995
+0.995 -0.995	- -	W1B W12B	W1C W12C	W1D W12D	- -
+0.844 -0.844	W2A W11A	W2B W11B	W2C W11C	W2D W11D	W2E W11E
+0.665 -0.665	W3A W10A	W3B W10B	W3C W10C	W3D W10D	W3E W10E
+0.470 -0.470	W4A W9A	W4B W9B	W4C W9C	- -	W4E W9E
+0.318 -0.318	W5A W8A	W5B W8B	W5C W8C	W5D W8D	W5E W8E
+0.131 -0.131	W6A W7A	W6B W7B	W6C W7C	W6D W7D	W6E W7E

ξ is proportion of wing chord aft of wing leading edge

η is proportion of wing semi-span from aircraft centreline

TABLE 2(b)

LOCATION OF STUB WING MEASURING STATIONS

η \ ξ	0.115	0.440	0.975
+0.990 -0.990	SW1A SW8A	SW1B SW8B	SW1C SW8C
+0.765 -0.765	SW2A SW7A	SW2B SW7B	SW2C SW7C
+0.542 -0.542	SW3A SW6A	SW3B SW6B	SW3C SW6C
+0.393 -0.393	SW4A SW5A	SW4B SW5B	SW4C SW5C

ξ is proportion of stub-wing chord aft of leading edge.

η is proportion of stub-wing semi-span from aircraft centreline.

TABLE 2(c)

LOCATION OF TAILPLANE MEASURING STATIONS

η \ ξ	0.042	0.375	0.625	0.986
+ 0.875 - 0.875	PT1A, ST1A PT4A, ST4A	PT1B, ST1B PT4B, ST4B	PT1C, ST1C PT4C, ST4C	PT1D, ST1D PT4D, ST4D
+ 0.484 - 0.484	PT2A, ST2A PT3A, ST3A	PT2B, ST2B PT3B, ST3B	PT2C, ST2C PT3C, ST3C	PT2D, ST2D PT3D, ST3D

ξ is proportion of tailplane chord aft of tailplane leading edge.

η is proportion of tailplane semi-span from boom centreline.

TABLE 2(d)

LOCATION OF FIN, BOOM, AND RUDDER MEASURING STATIONS

B.S. \ W.L.	- 305	0	+ 350	+ 510
2464		PB1V, SB1V PB1H, SB1H		
3074		PB2V, SB2V PB2H, SB2H		
3684		PB3V, SB3V PB3H, SB3H		
4446		PB4V, SB4V PB4H, SB4H		
4890	PF4A SF4A	PF3A SF3A	PF2A SF2A	PF1A SF1A
5110	PF4B SF4B	PF3B SF3B	PF2B SF2B	PF1B SF1B
5620	PF4C SF4C	PF3C SF3C	PF2C SF2C	PF1C SF1C

B.S. - Body Station in millimetres from main wing root leading edge.

W.L. - Water Line in millimetres from boom centreline.

TABLE 3

Summary of modes measured in ground resonance tests.

DESCRIPTION OF MODE	NATURAL FREQUENCY Hz T-300 (Ref. 1)	NATURAL FREQUENCY Hz T-400	% DAMPING CRITICAL	Fig No.
Symmetric lateral bending of booms	-	3.8	1.2	8
Antisymmetric lateral bending of booms	5.14	4.4	1.0	9
Antisymmetric vertical bending of booms	6.07	4.8	2.8	10
Symmetric vertical bending of booms	-	6.7	2.8	11
Symmetric torsion of booms	9.9	9.23	1.7	12
Antisymmetric torsion of booms	10.5	9.43	1.5	13
Elevator rotation - stick free	9.7	10.4	-	-
Symmetric Wing bending	11.4	11.4	-	-
Elevator rotation - stick fixed	14.2	12.0	-	-
Antisymmetric Wing bending	14.4	14.4	-	-
2nd vertical boom bending*	21.5*	17.8*	2	14
Rudder anti-phase rotation	21.6	23.0	-	-
Aileron symmetric rotation	23.4	25.0	-	-
Stub-wing symmetric bending	30.8	29.9	2	15
Symmetric wing torsion	35.5	35.6	-	-
Rudder bending with tailplane torsion	38.0	38.0	-	-
Elevator antisymmetric torsion	38.4	38.4	-	-
Antisymmetric wing torsion	39.4	39.4	-	-
Rudder bending	43.2	43.2	-	-
Symmetric tailplane bending	46.5	46.5	-	-

* Note. 1. The mode at 21.5 hertz on the T-300 was not measured on the same aircraft as the other modes.

2. The mode at 17.8 hertz on the T-400 was subsequently increased to 22 hertz by the addition of the dorsal stabiliser fin.

TABLE 4

LOCATION OF ACCELEROMETERS FOR FLIGHT TESTS

Starboard Aileron	-	outboard trailing edge W2E
Starboard Wing	-	between W2B and W2C
Starboard tailplane	-	between ST3A and ST3B
Starboard elevator	-	trailing edge ST3D
Starboard fin	-	location SF3A
Starboard rudder	-	trailing edge 75mm below W.L.
Starboard boom	-	between SB3V and SB4V
Port boom	-	between PB3V and PB4V

TABLE 5

SCHEDULE OF TEST FLIGHTS - FLUTTER CLEARANCE

FLIGHT 1 - 9th November 1984

Air speed 80 knots	Engine speed 2000 RPM
Air speed 80 knots	Engine speed 2100 RPM
Air speed 80 knots	Engine speed 2200 RPM
Air speed 80 knots	Engine speed 2300 RPM
Air speed 80 knots	Engine speed 2400 RPM
Air speed 80 knots	Engine speed 2500 RPM
Air speed 80 knots	Engine speed 2600 RPM

FLIGHT 2 - 9th November 1984

Air speed 80 knots	Engine speed 2500 RPM
Air speed 90 knots	Engine speed 2500 RPM
Air speed 100 knots	Engine speed 2500 RPM
Air speed 110 knots	Engine speed 2500 RPM

FLIGHT 3 - 10th November 1984

Air speed 110 knots	Engine speed 2500 RPM
Air speed 120 knots	Engine speed 2500 RPM
Air speed 130 knots	Engine speed 2500 RPM

FLIGHT 4 - 12th November 1984

Air speed 130 knots	Engine speed 2500 RPM
Air speed 140 knots	Engine speed 2500 RPM

TABLE 5 (CONTD)

FLIGHT 5 - 13th November 1984

Air speed 140 knots	Engine speed 2300 RPM
Air speed 150 knots	Engine speed 2300 RPM

FLIGHT 6 - 14th November 1984

Air speed 150 knots	Engine speed 2300 RPM
Air speed 162 knots	Engine speed 2300 RPM

FLIGHT 7 - 14th November 1984

Air speed 110 knots	Engine speed 2300 RPM
Air speed 120 knots	Engine speed 2300 RPM
Air speed 130 knots	Engine speed 2300 RPM

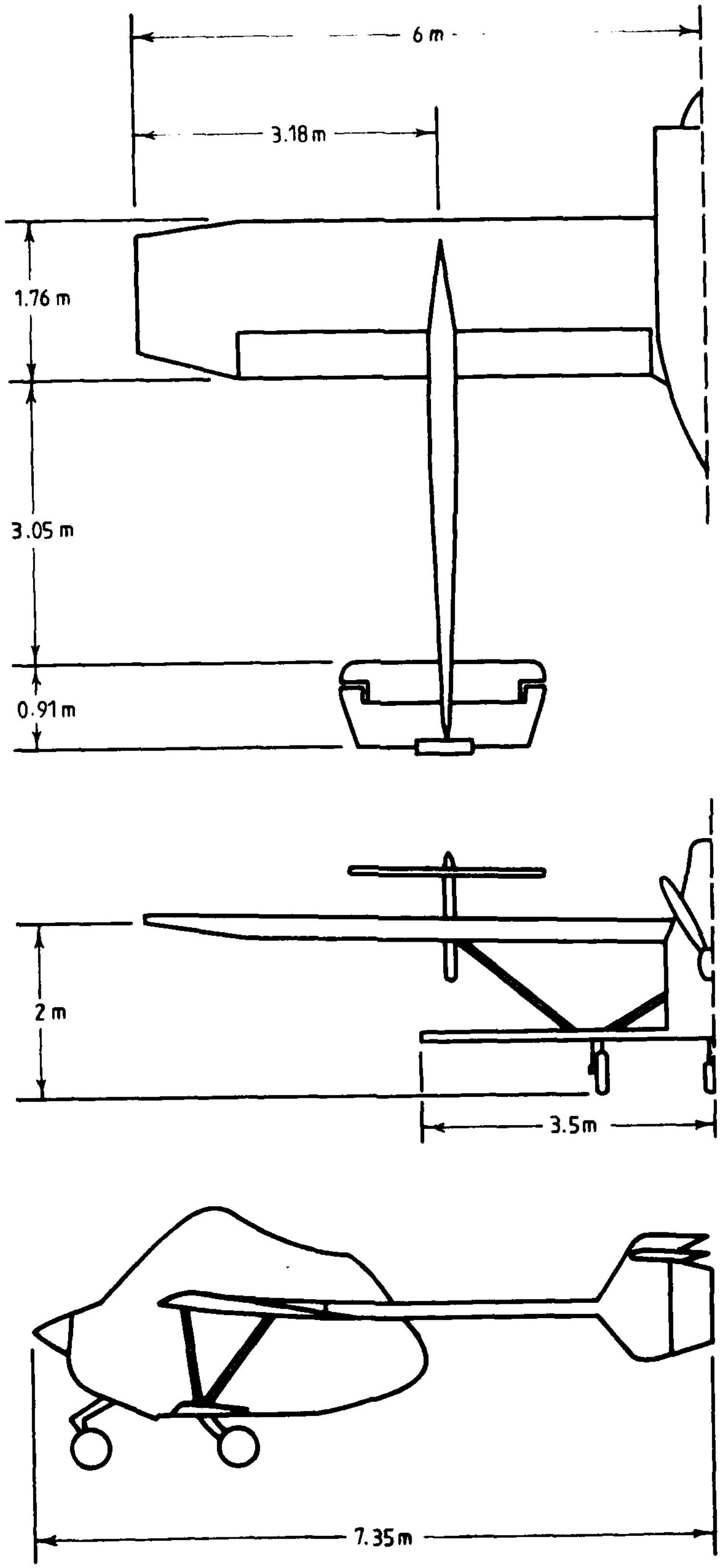


FIG. 1(a) GENERAL OUTLINE OF AIRCRAFT WITH MAJOR DIMENSIONS

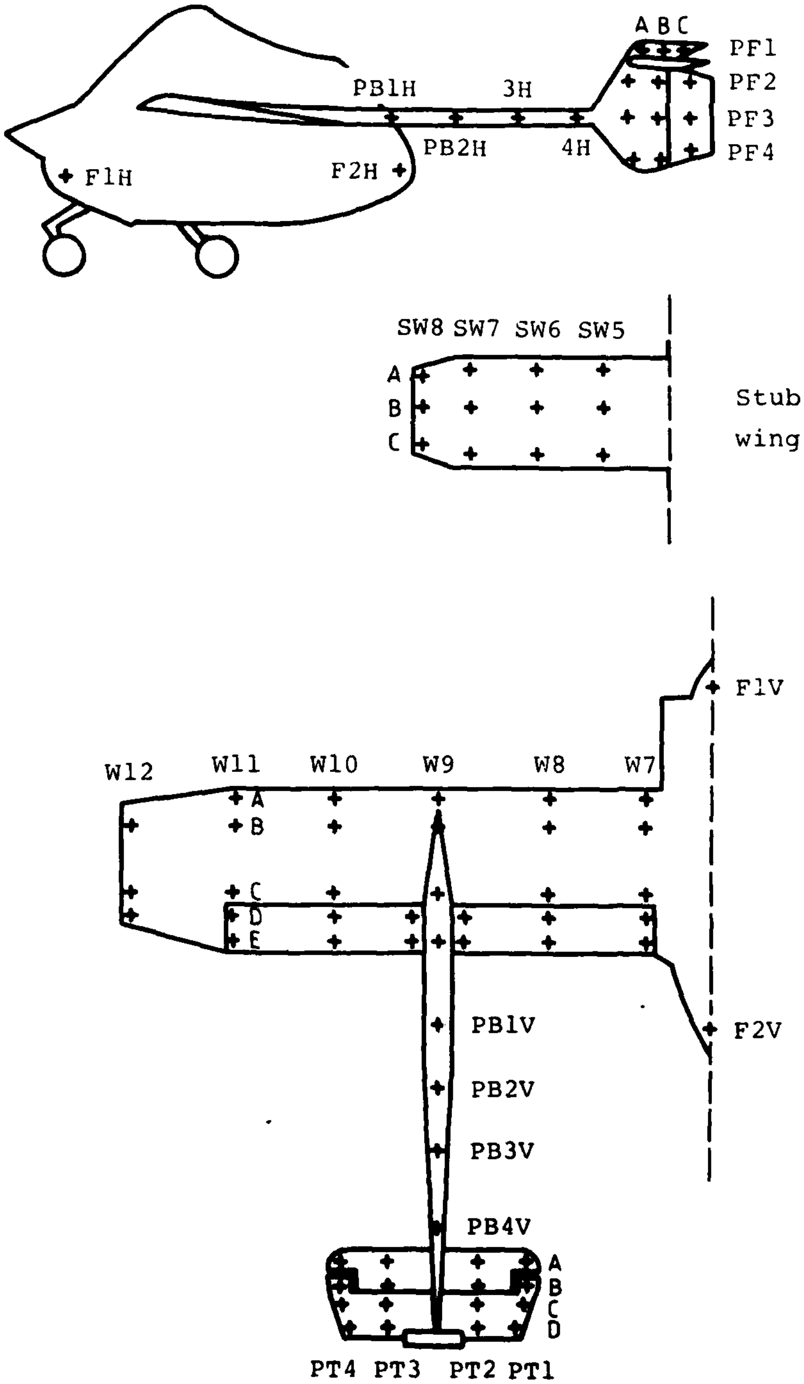


FIG. 1(b) LOCATIONS OF MEASURING STATIONS
(ONLY HALF SHOWN HERE)

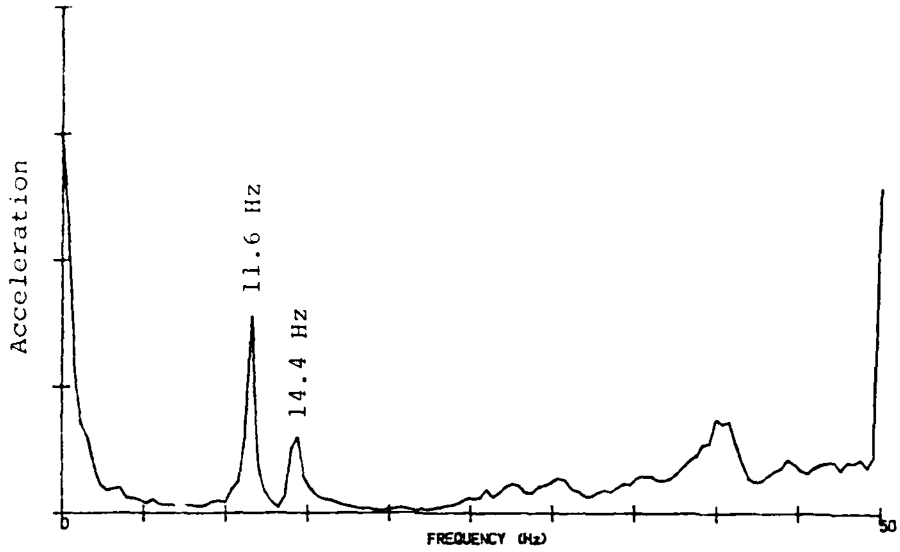


FIG. 2 RESPONSE AT W11B

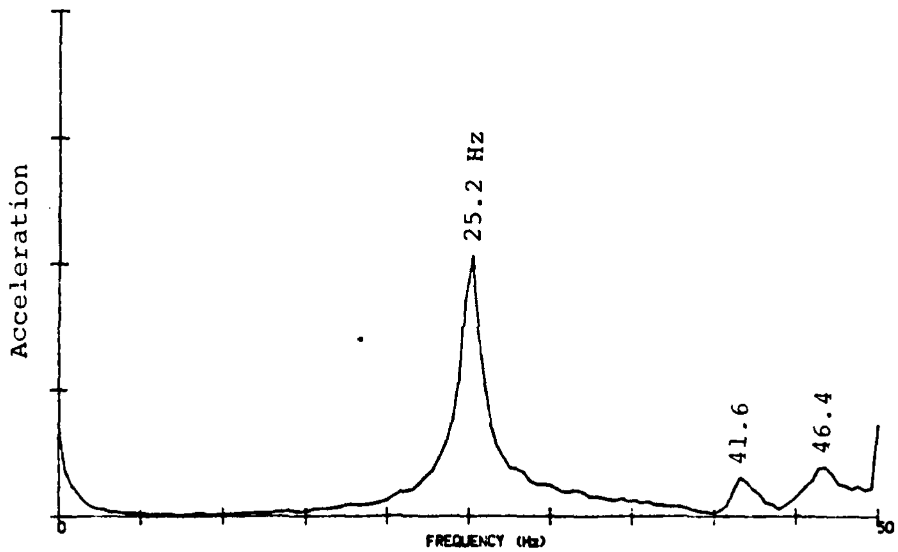


FIG. 3 RESPONSE AT SW8A

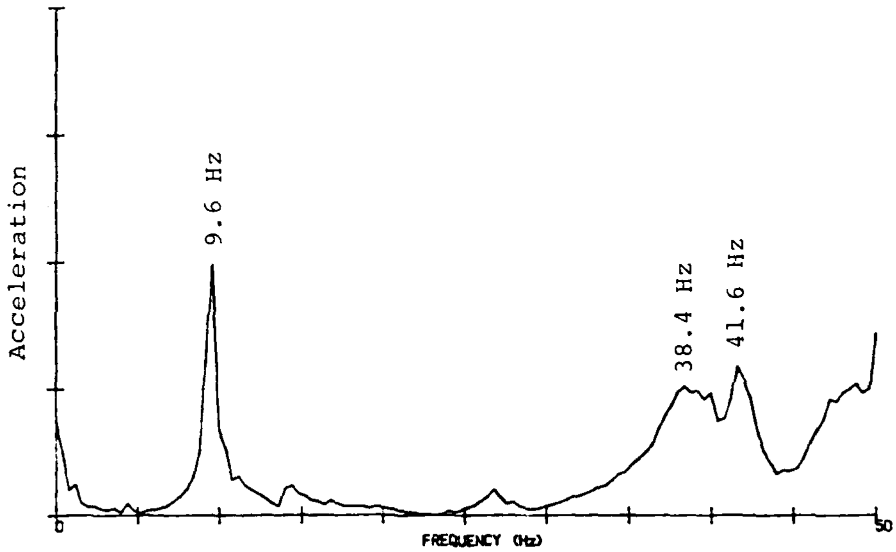


FIG. 4 RESPONSE AT PF4B

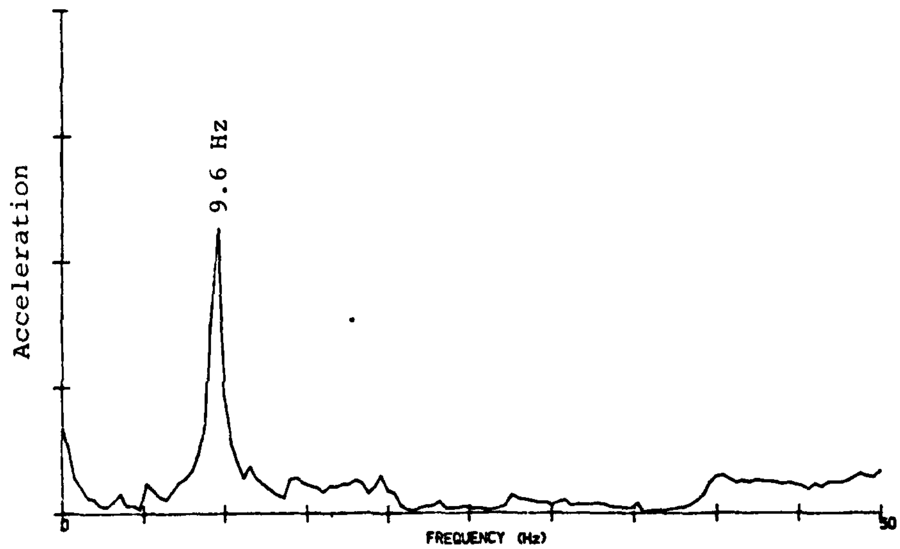


FIG. 5 RESPONSE AT PT4A

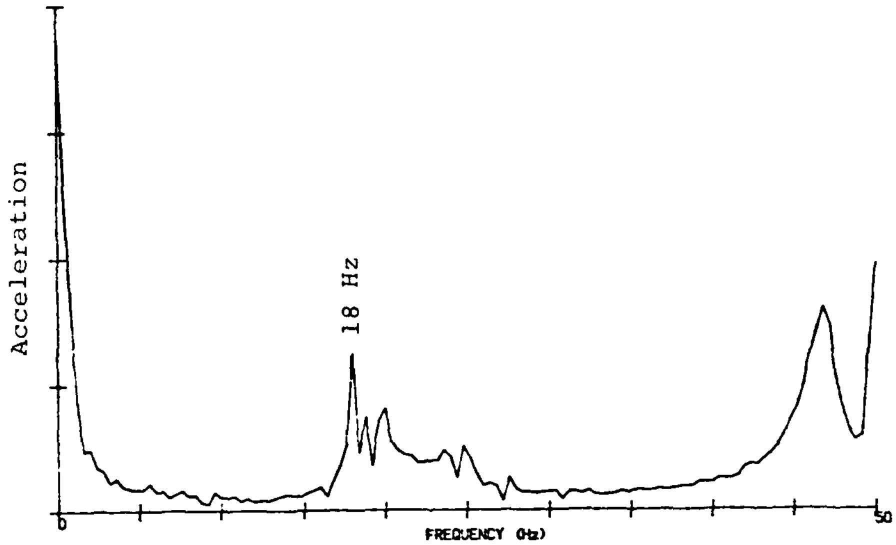


FIG. 6 RESPONSE AT SB4V

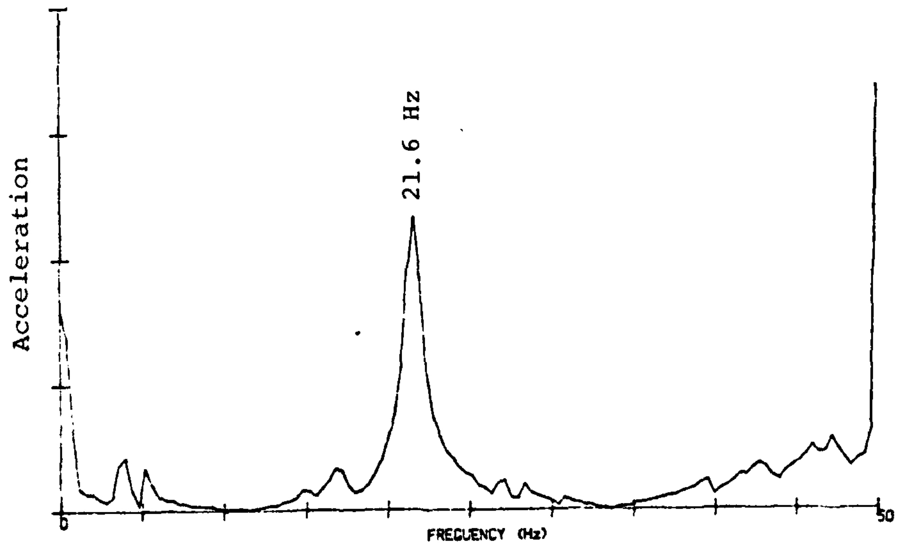


FIG. 7 T300 AIRCRAFT - RESPONSE AT PB4V

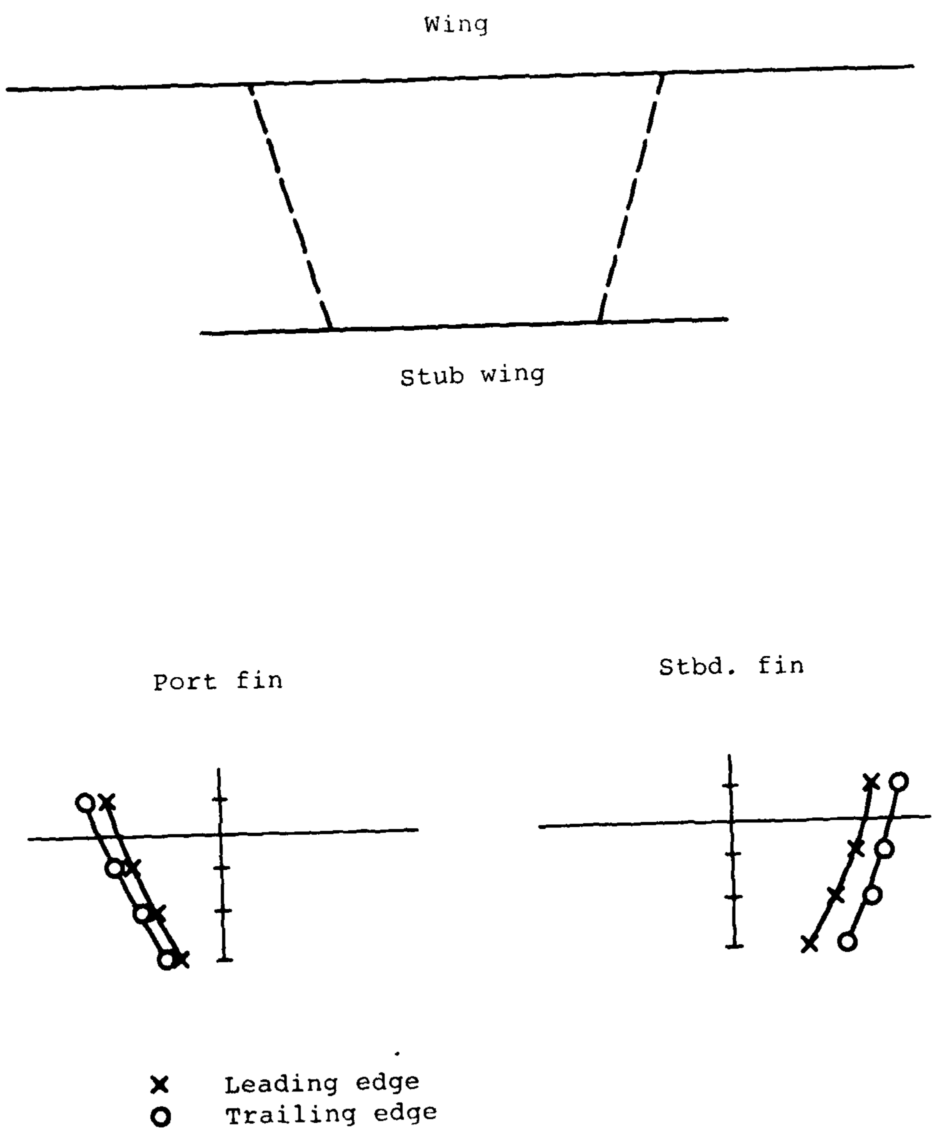


FIG. 8(a) MODE AT 3.8 Hz

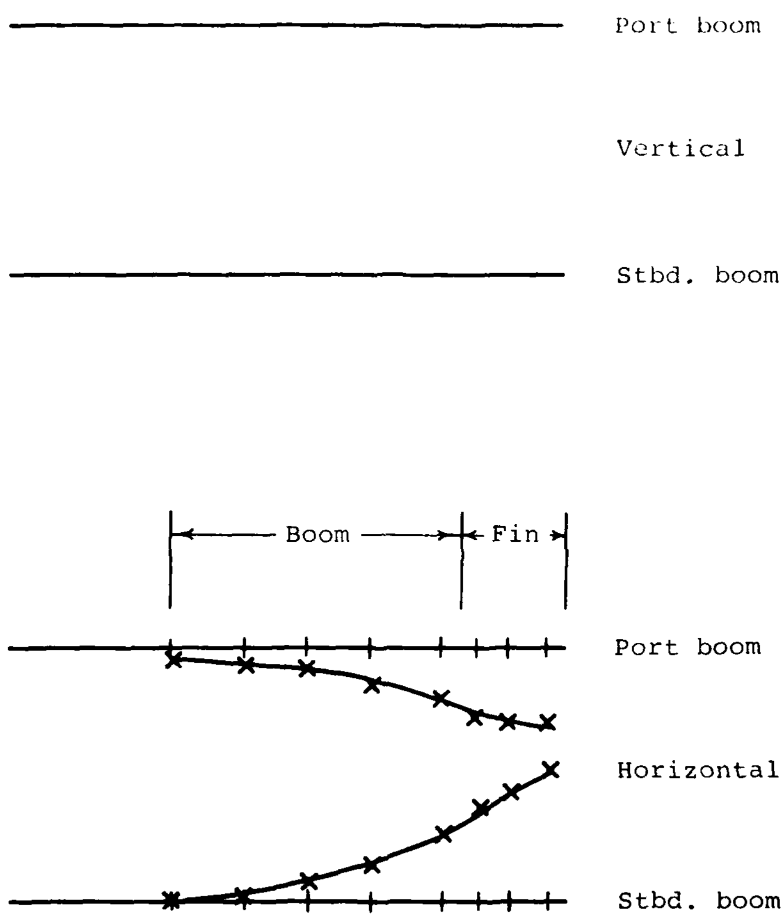


FIG 8(b) MODE AT 3.8 Hz

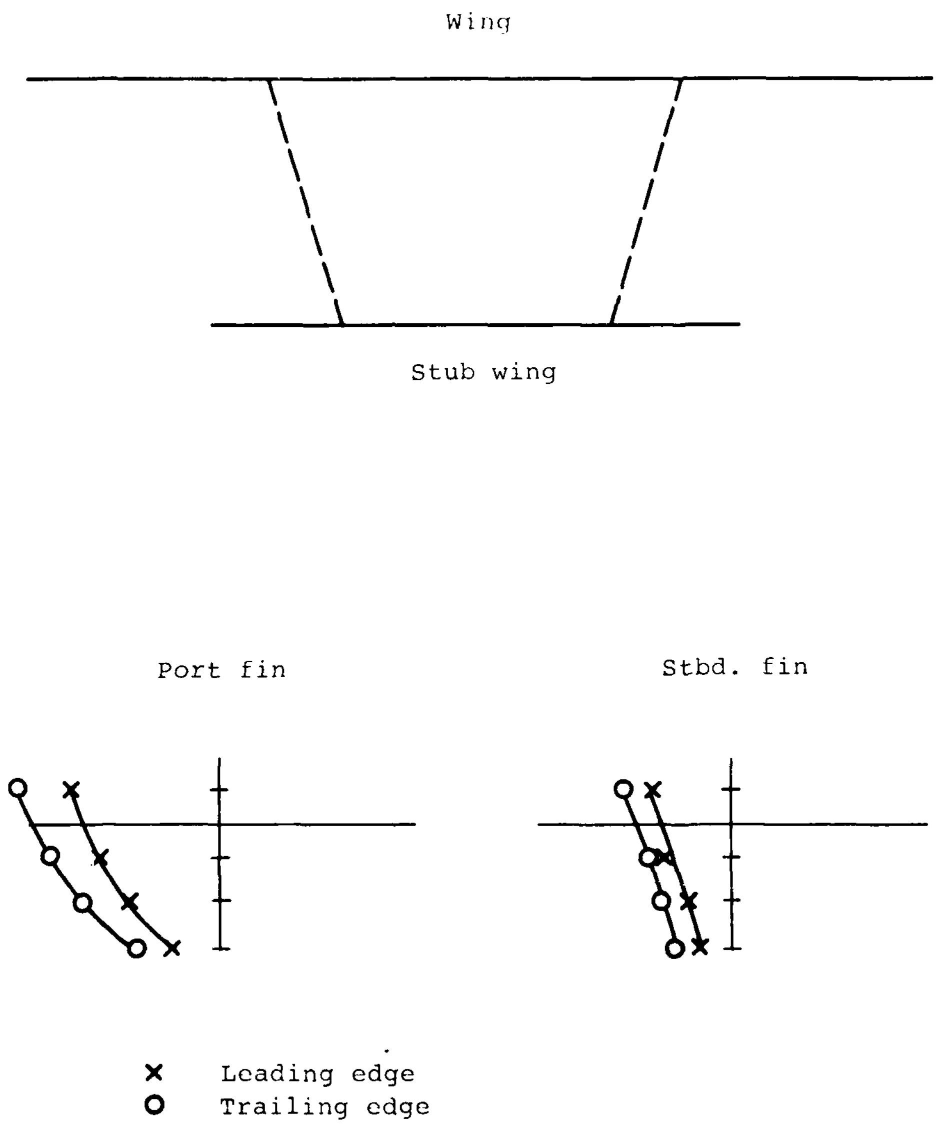


FIG 9(a) MODE AT 4.4 Hz

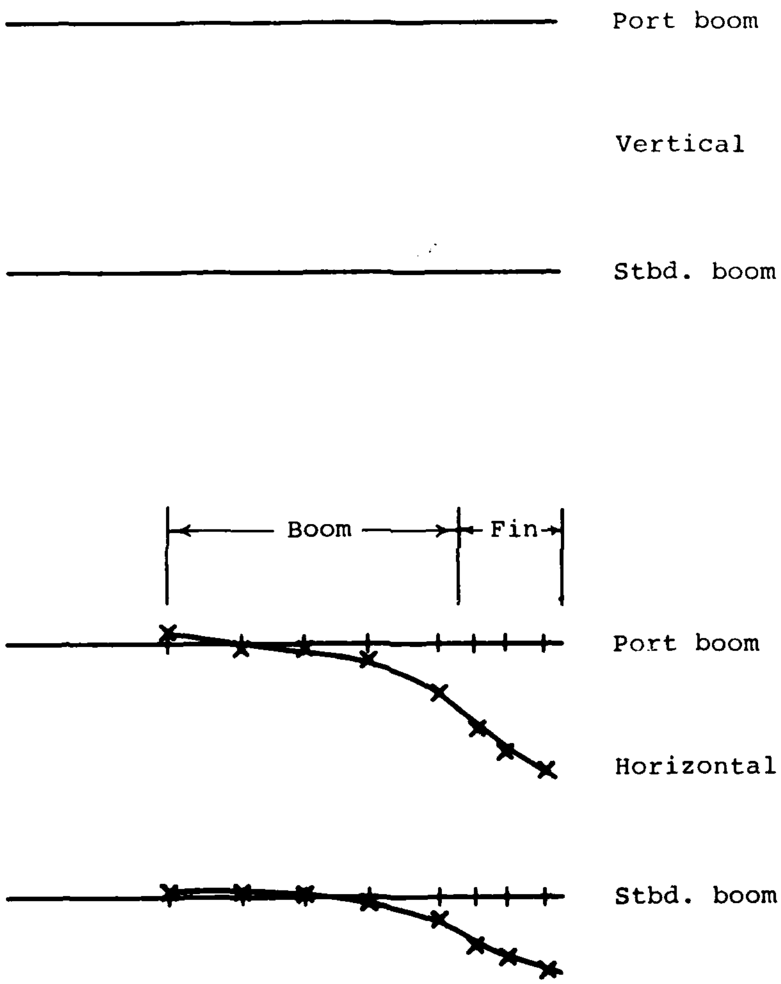


FIG. 9(b) MODE AT 4.4 Hz

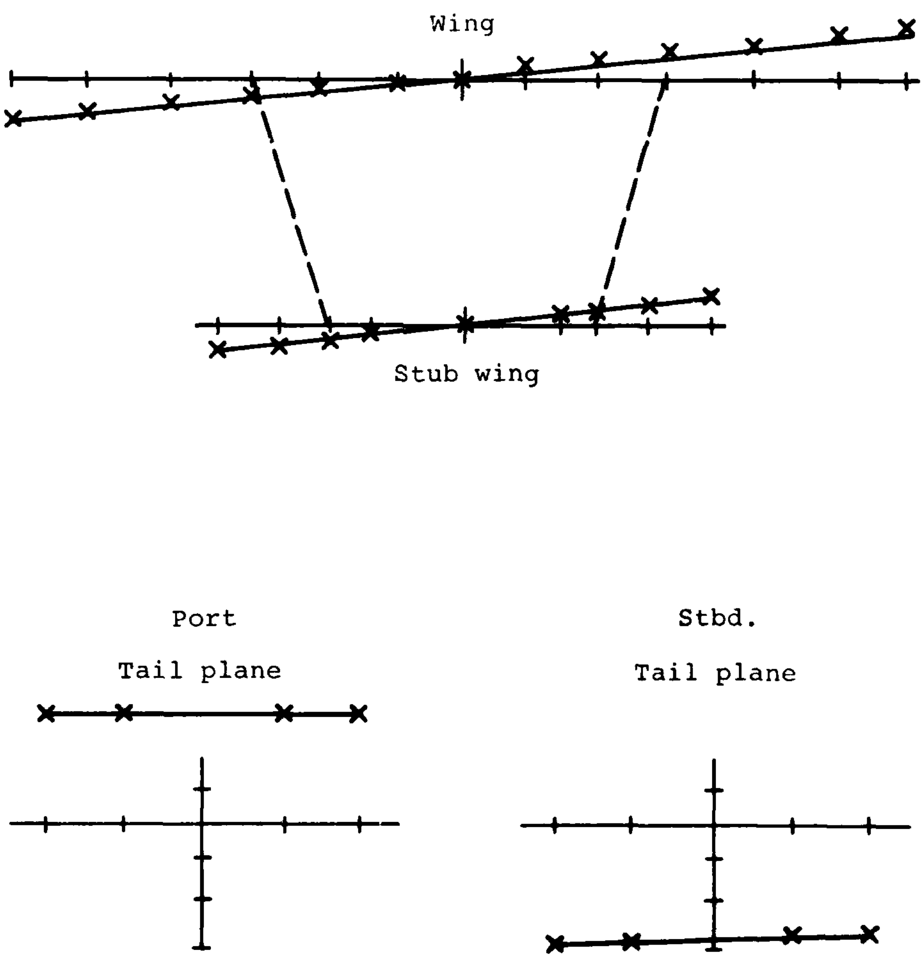


FIG. 10(a) MODE AT 4.8 Hz

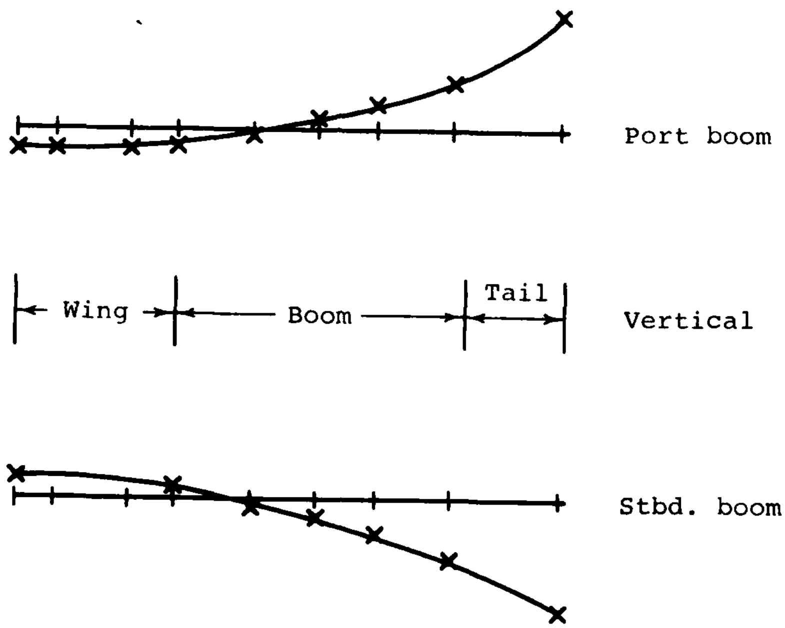


FIG. 10(b) MODE AT 4.8 Hz

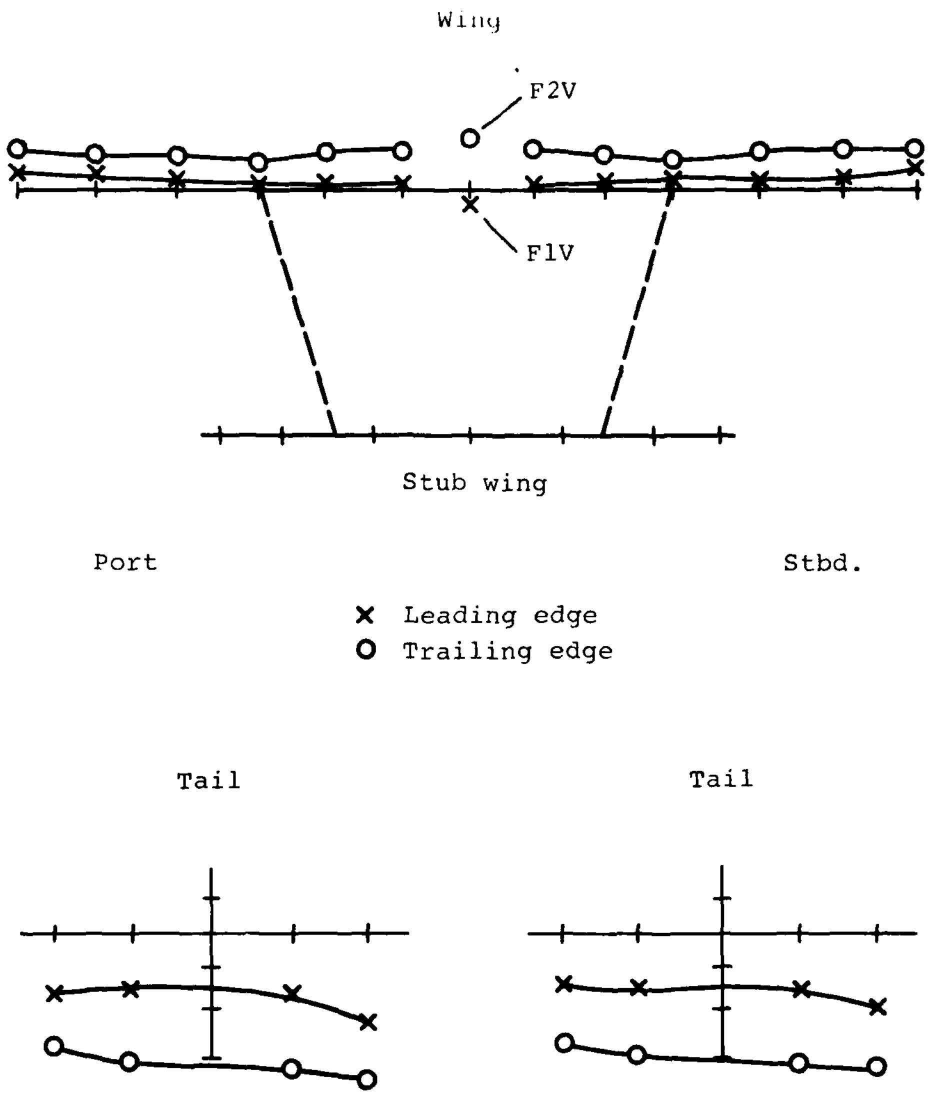


FIG. 11(a)   MODE AT 6.7 Hz

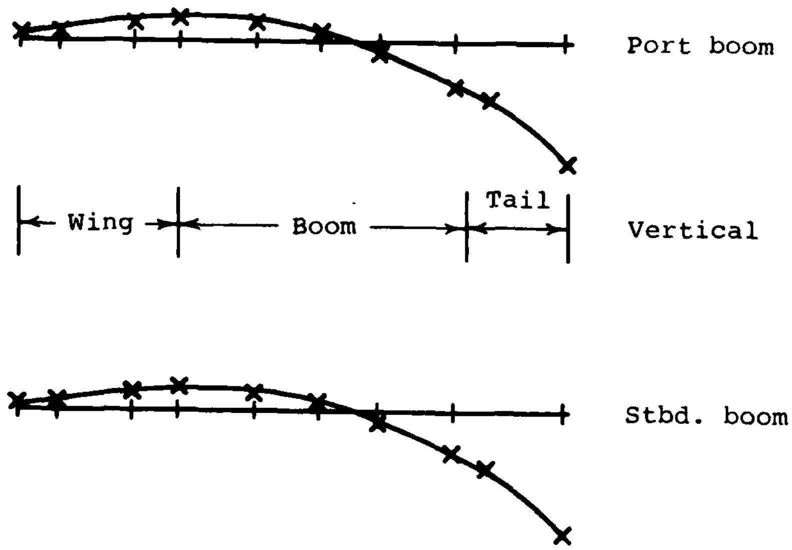


FIG. 11(b) MODE AT 6.7 Hz

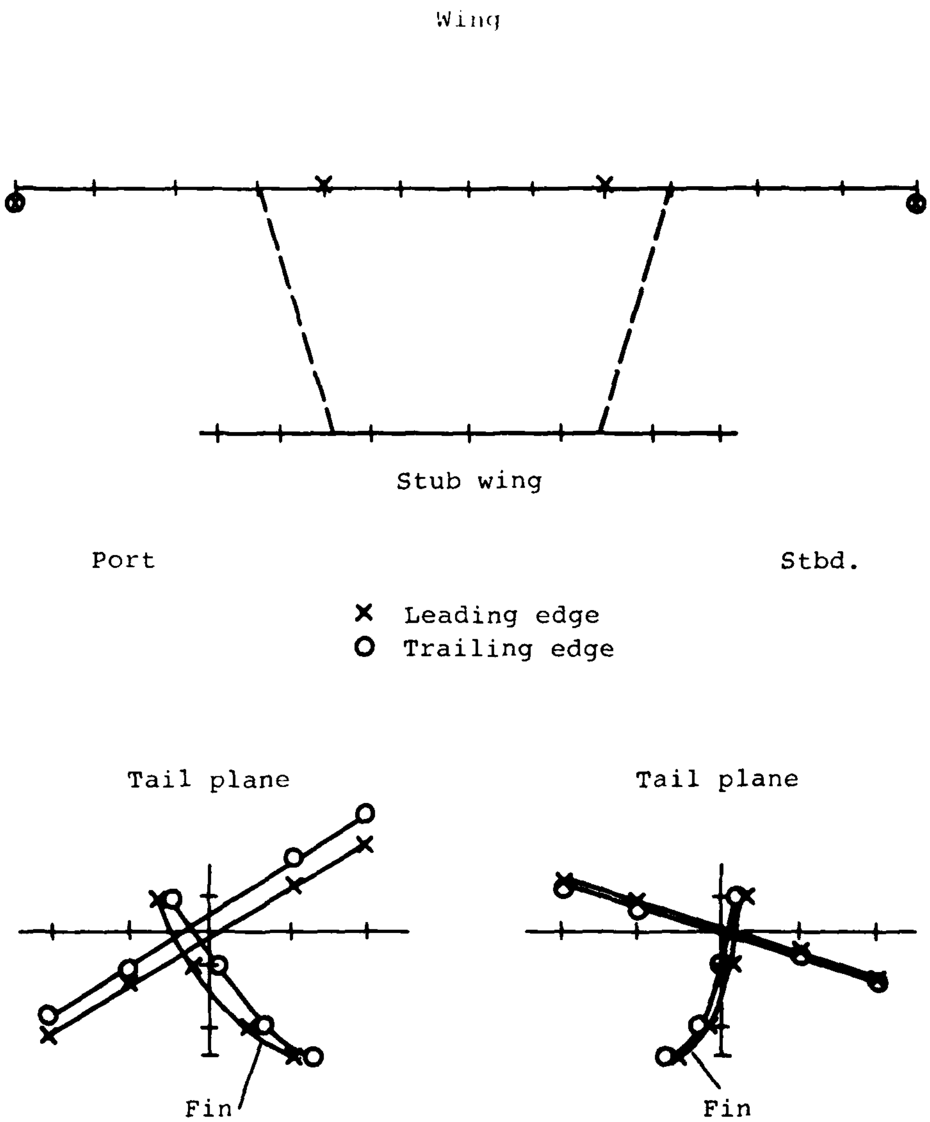


FIG. 12(a) MODE AT 9.23 Hz

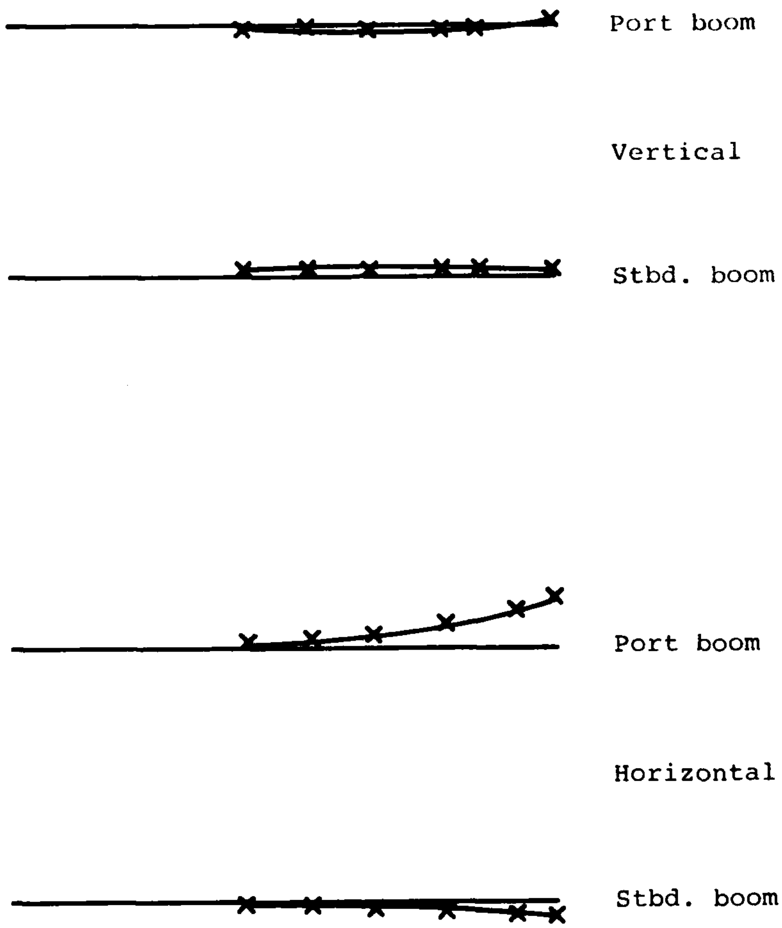


FIG 12(b) MODE AT 9.23 Hz

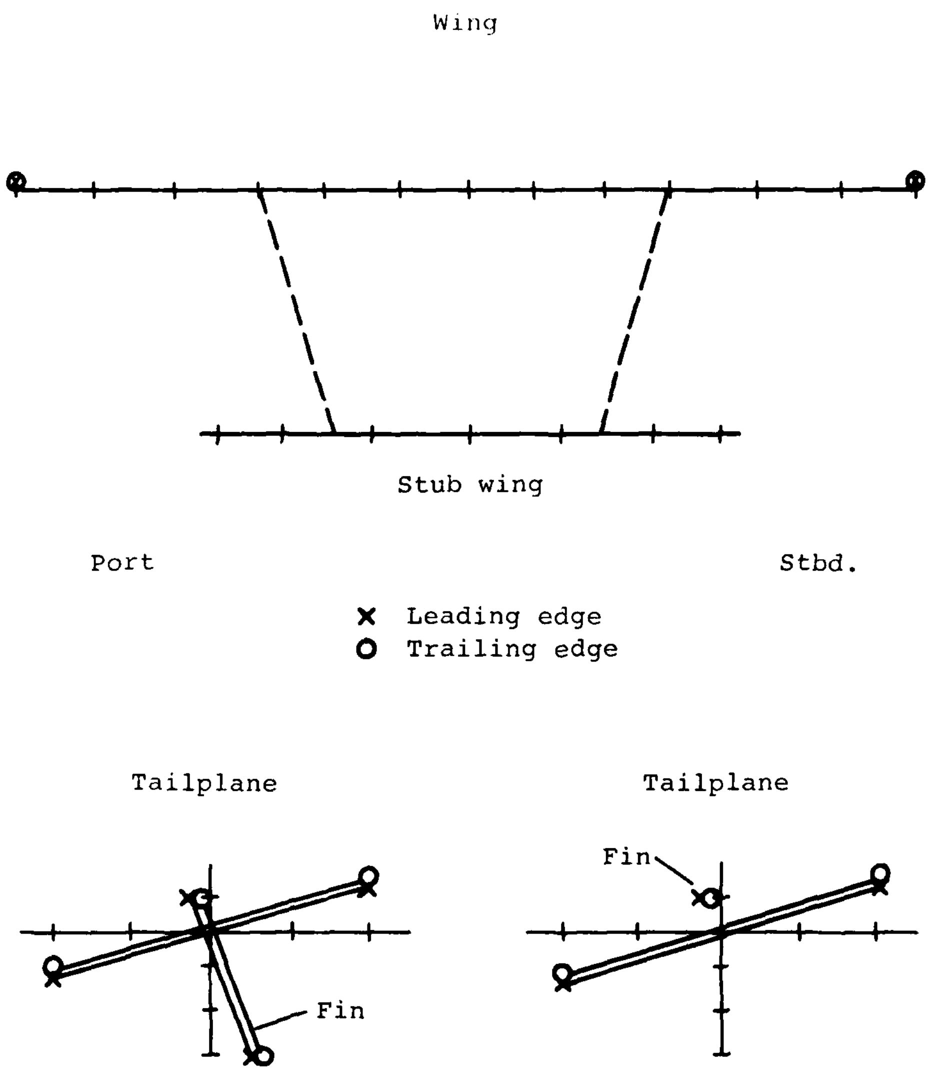


FIG. 13 MODE AT 9.43 Hz

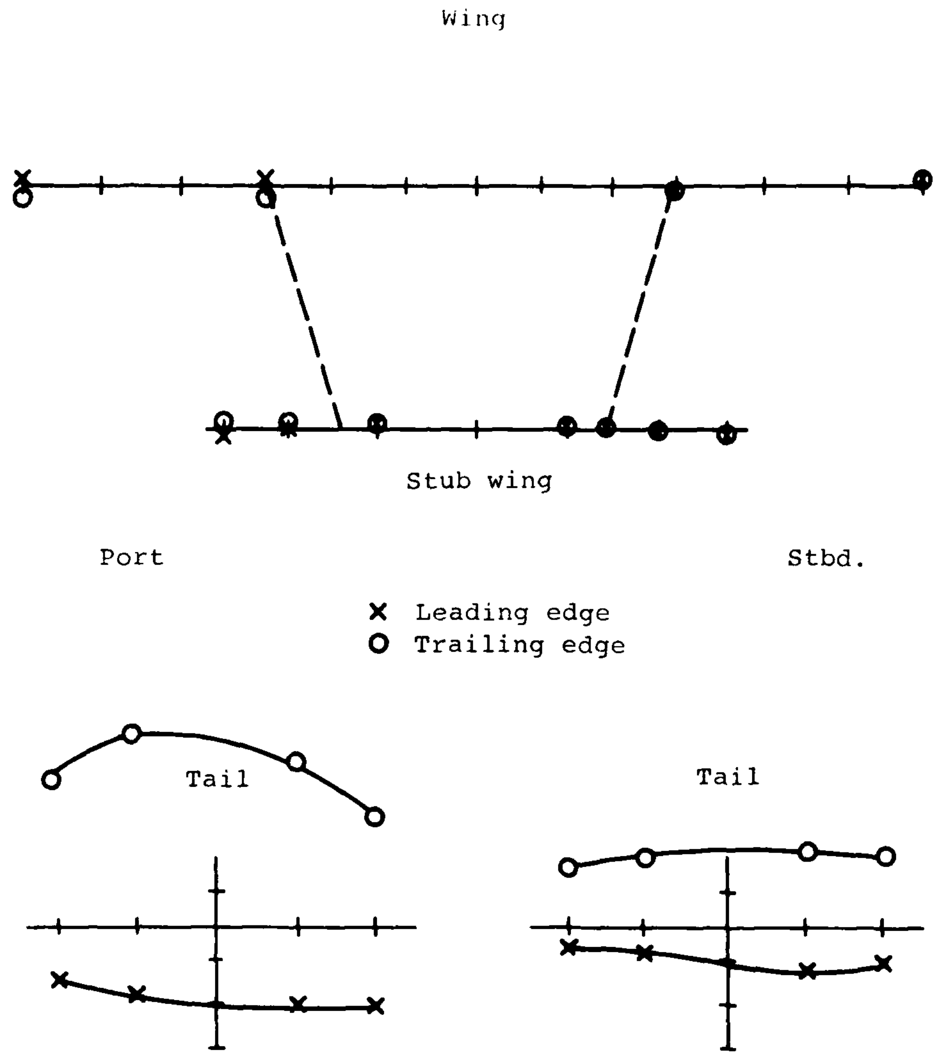
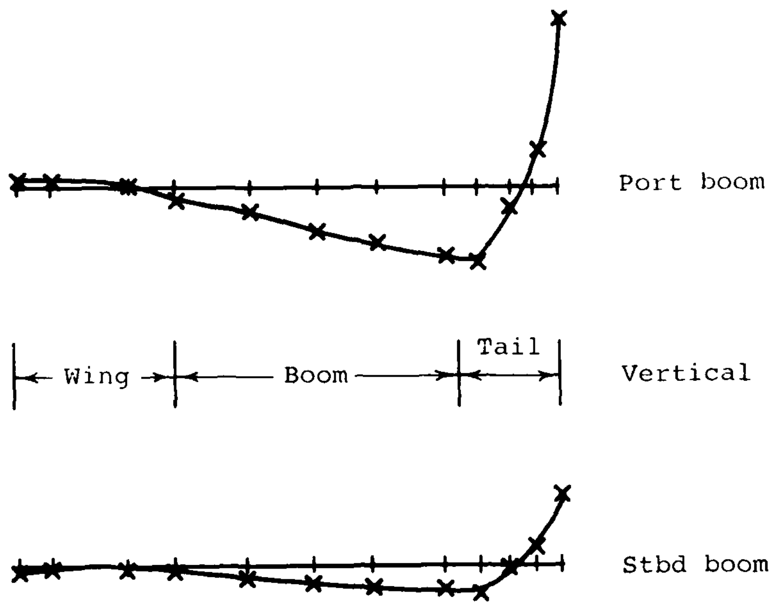
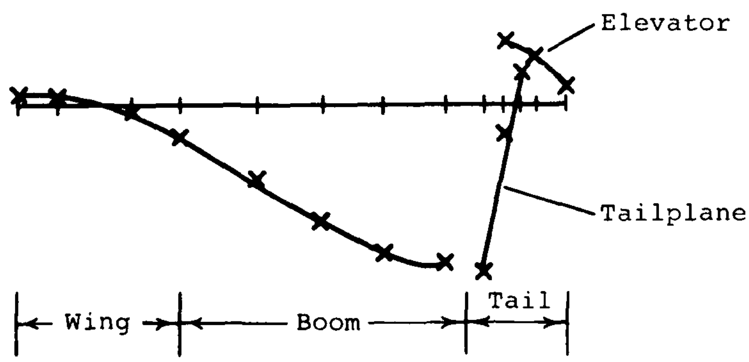


FIG. 14(a) MODE AT 17.8 Hz



Mode with elevator clamped



Mode on port tail with elevator free

FIG. 14(b) MODE AT 17.8 Hz

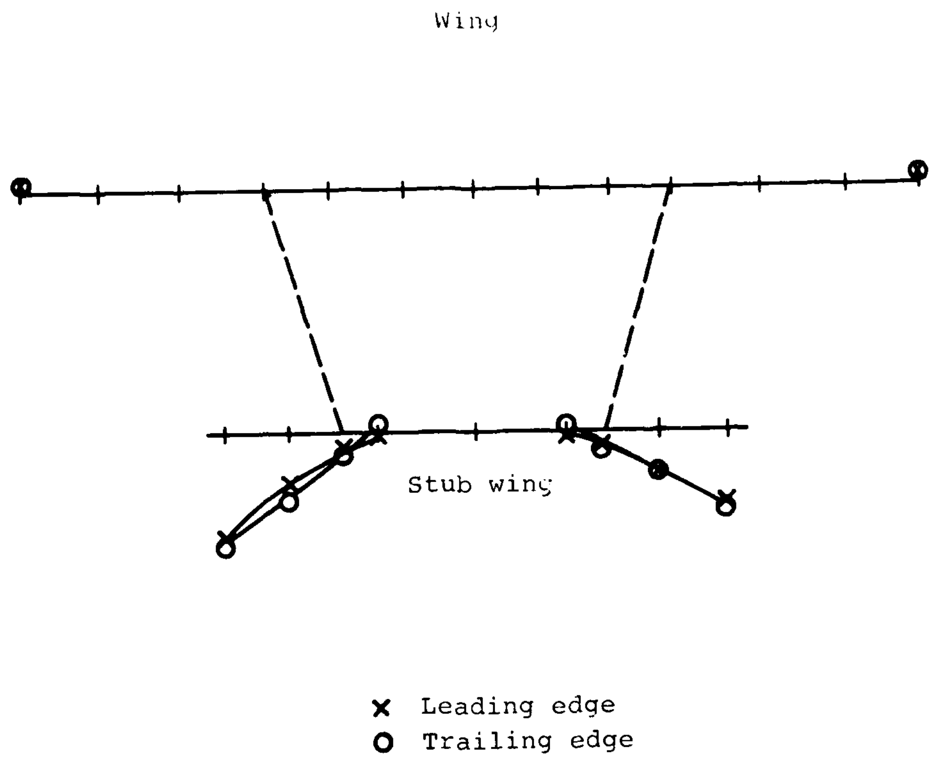


FIG. 15 MODE AT 29.95 Hz

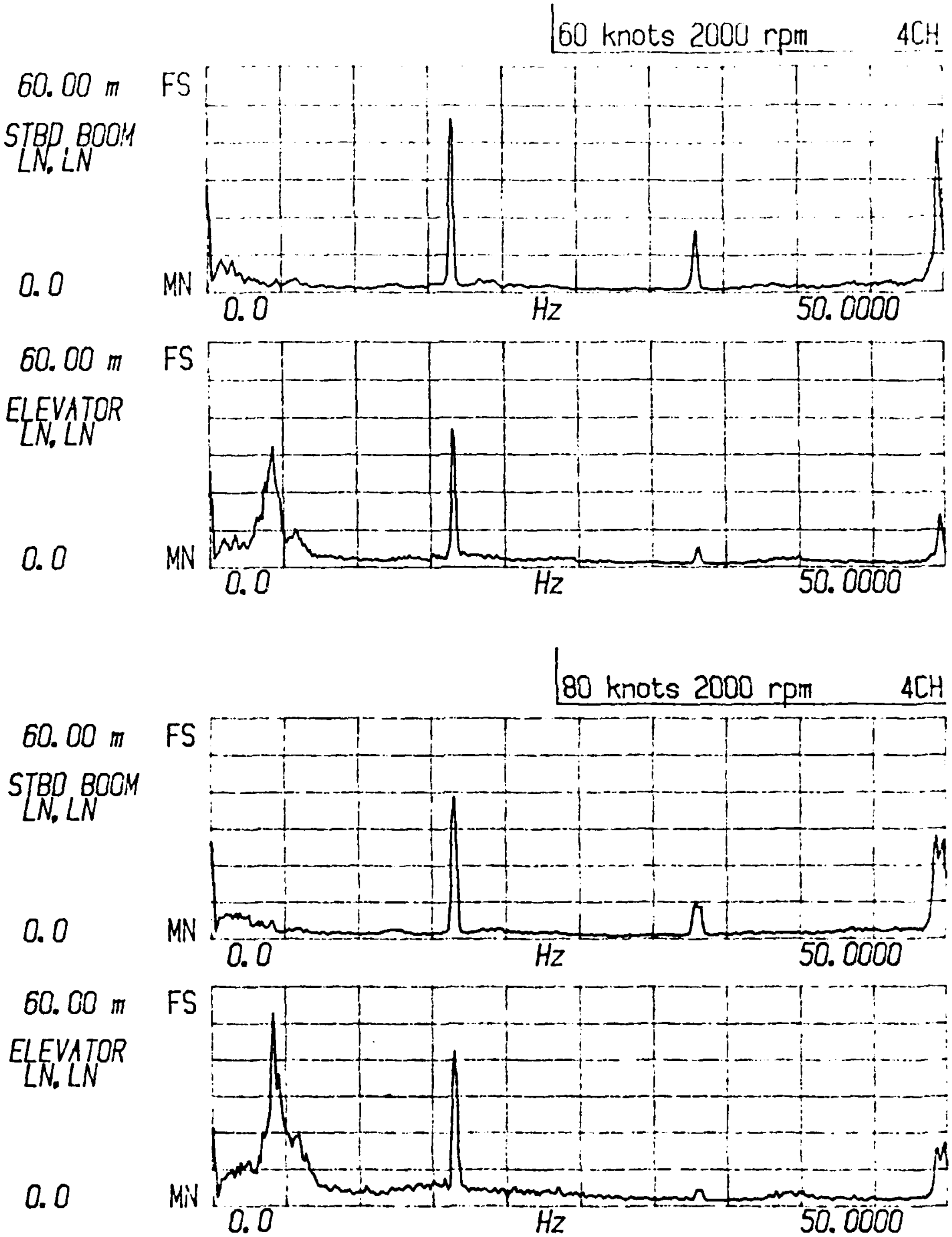


FIG. 16 RESPONSE TO TURBULENCE
- PRELIMINARY FLIGHTS

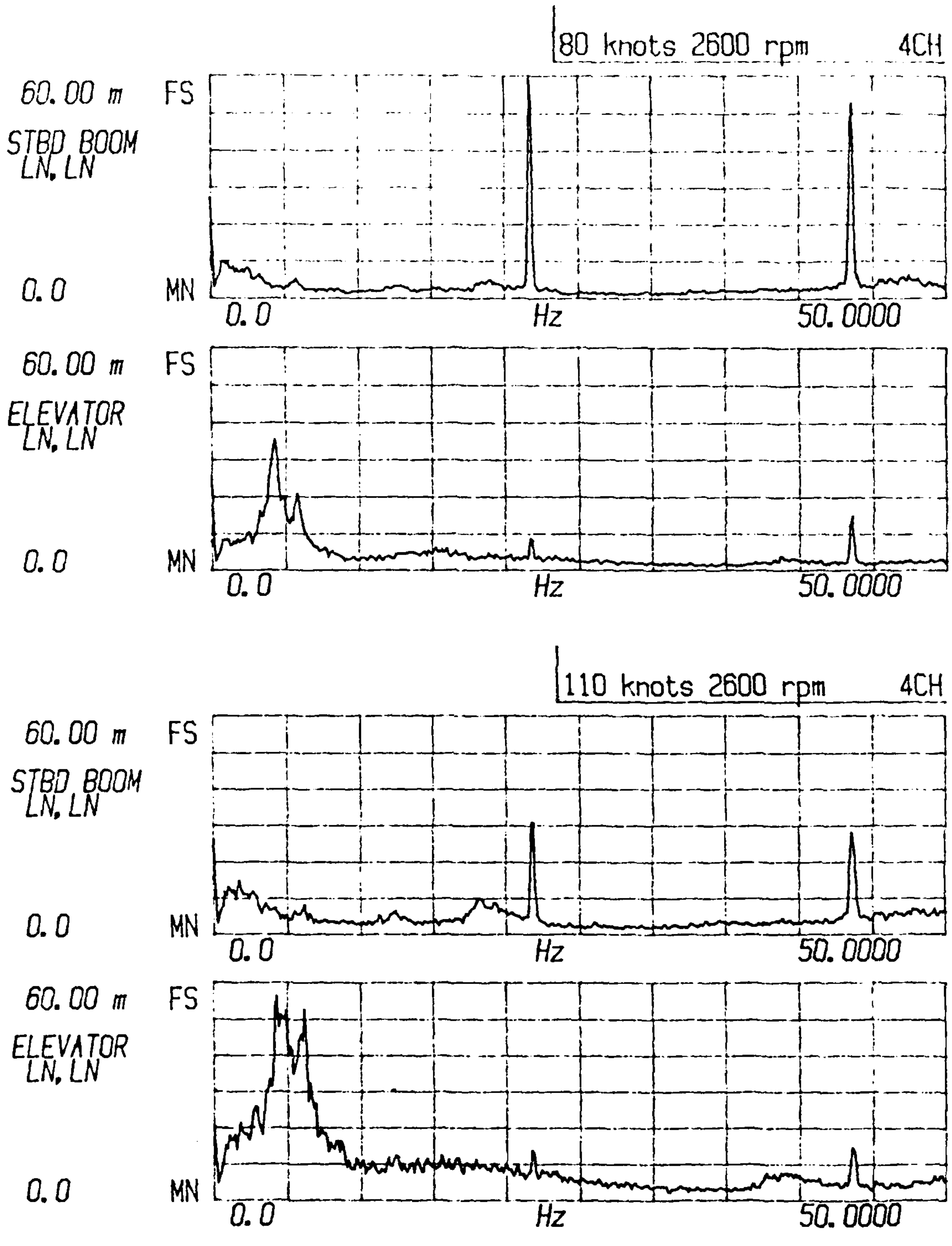


FIG. 17 RESPONSE TO TURBULENCE
- PRELIMINARY FLIGHTS

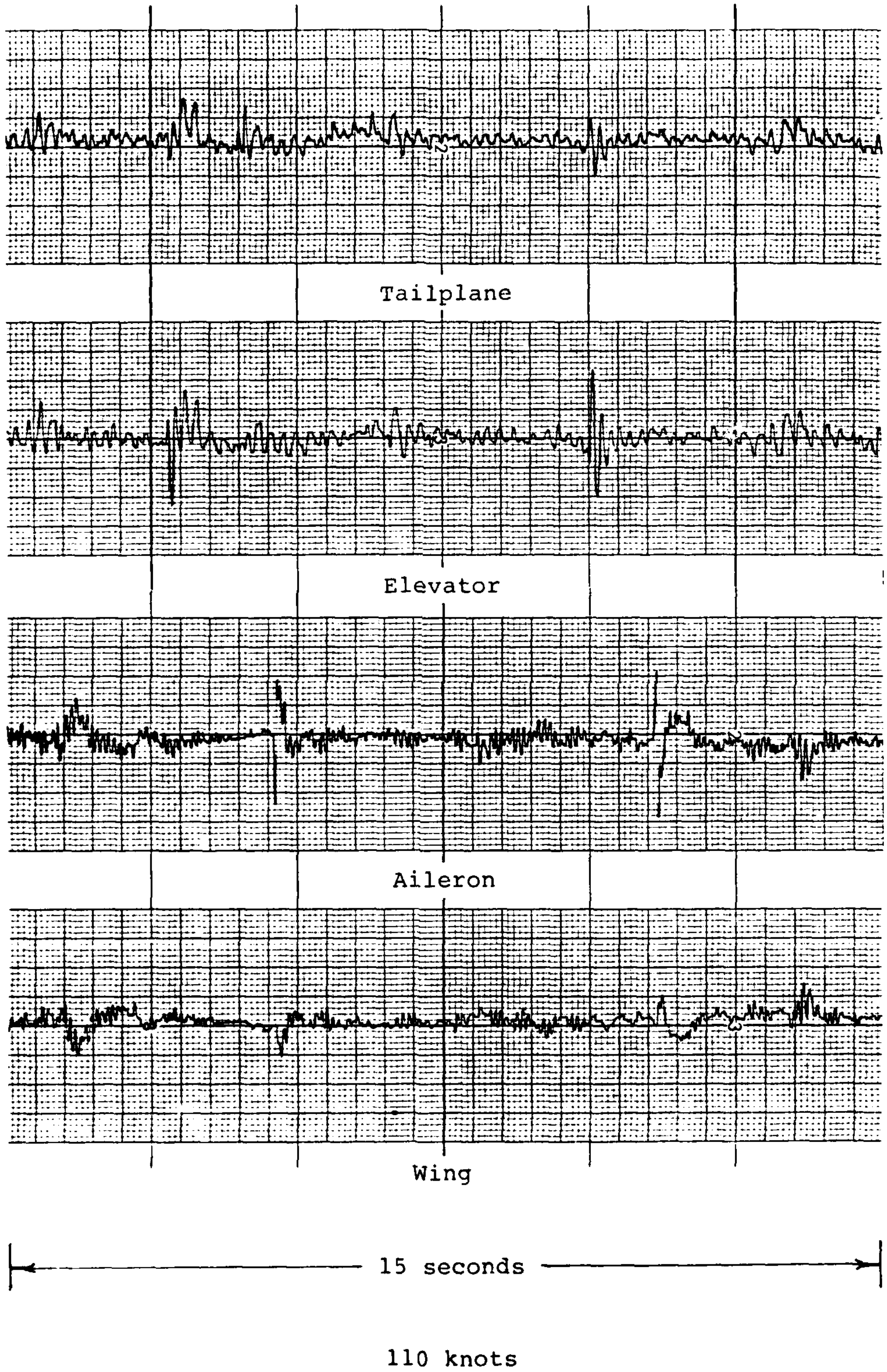
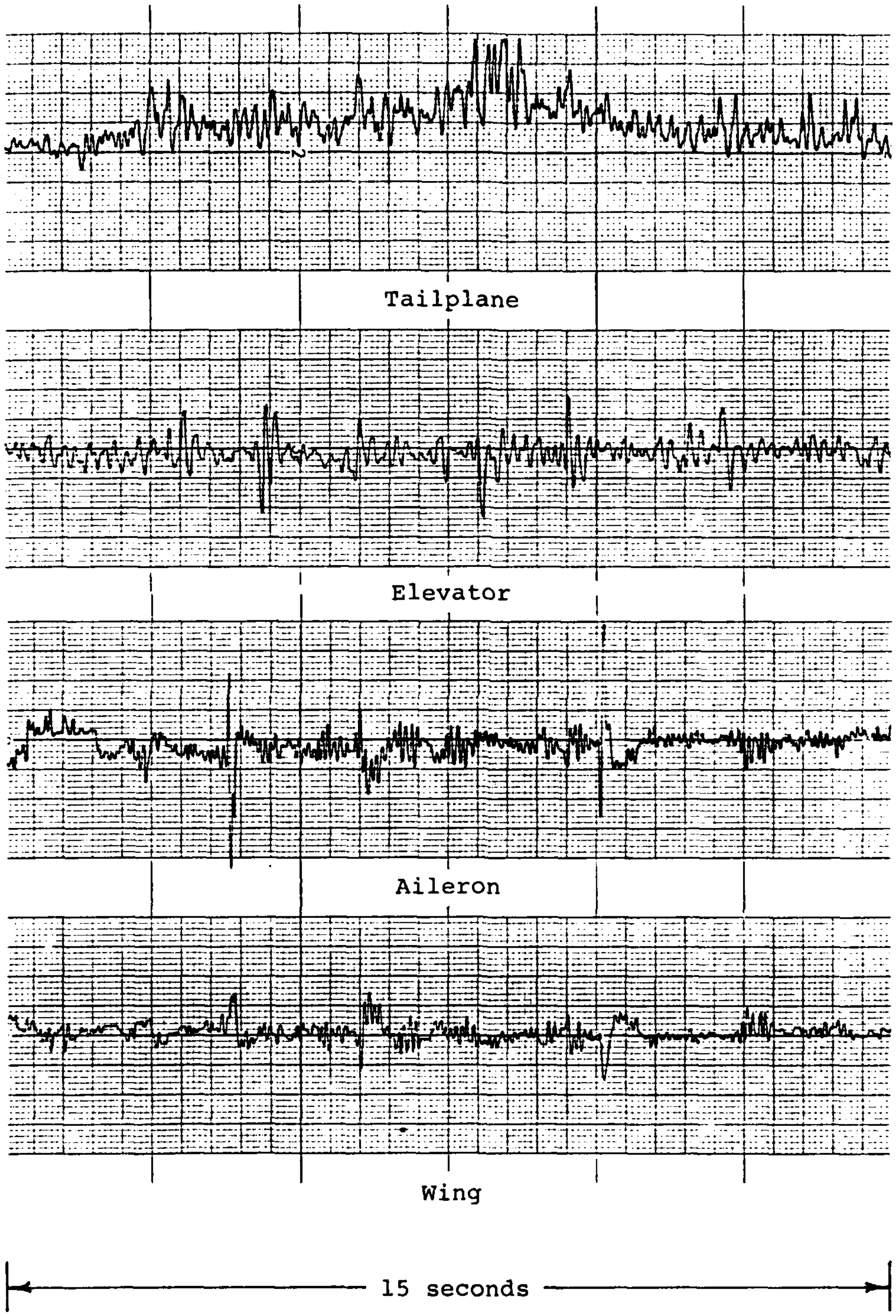


FIG. 18 RESPONSE TO STICK RAPS AT 110 KNOTS



130 knots

FIG. 19 RESPONSE TO STICK RAPS AT 130 KNOTS

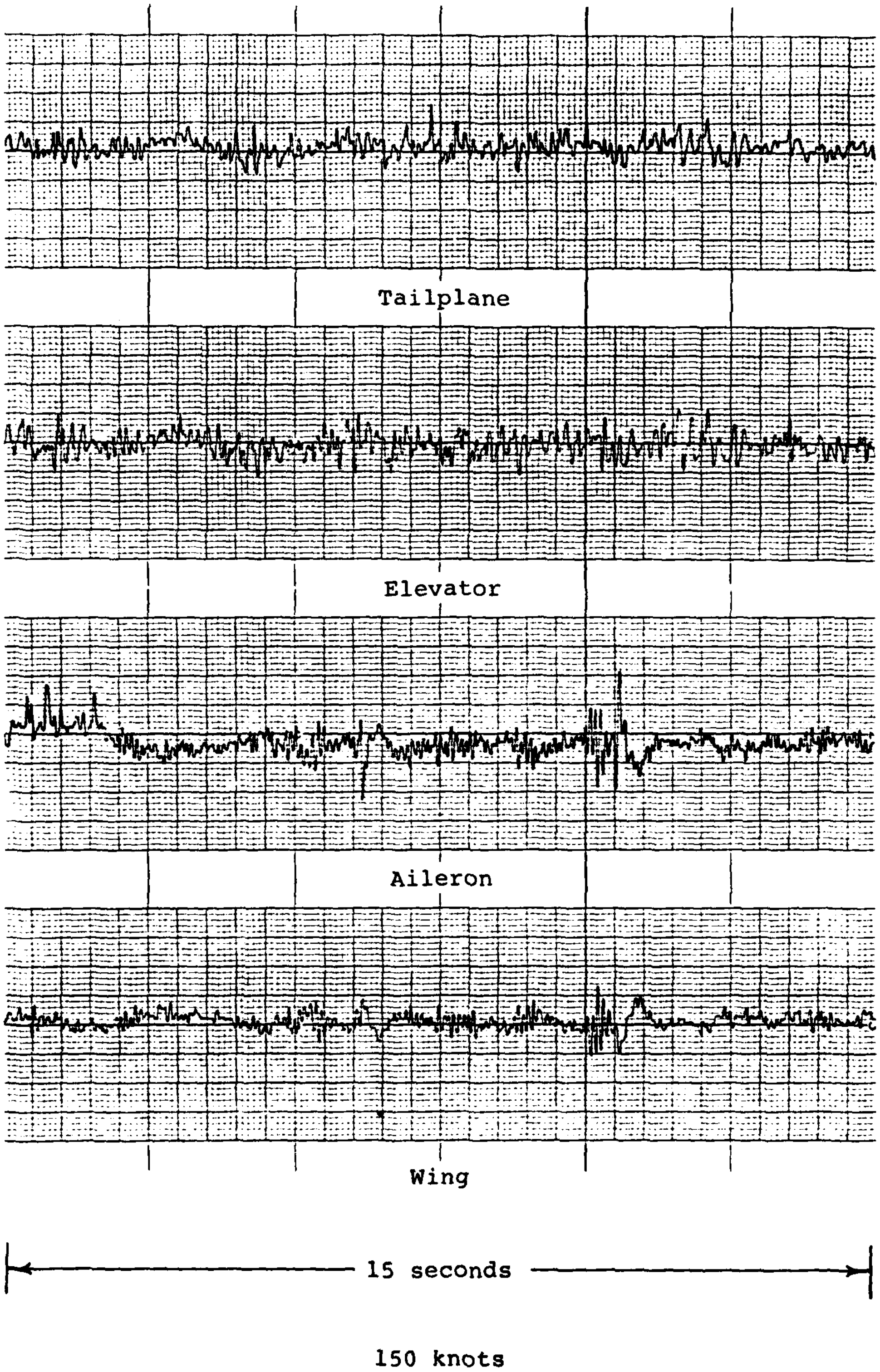
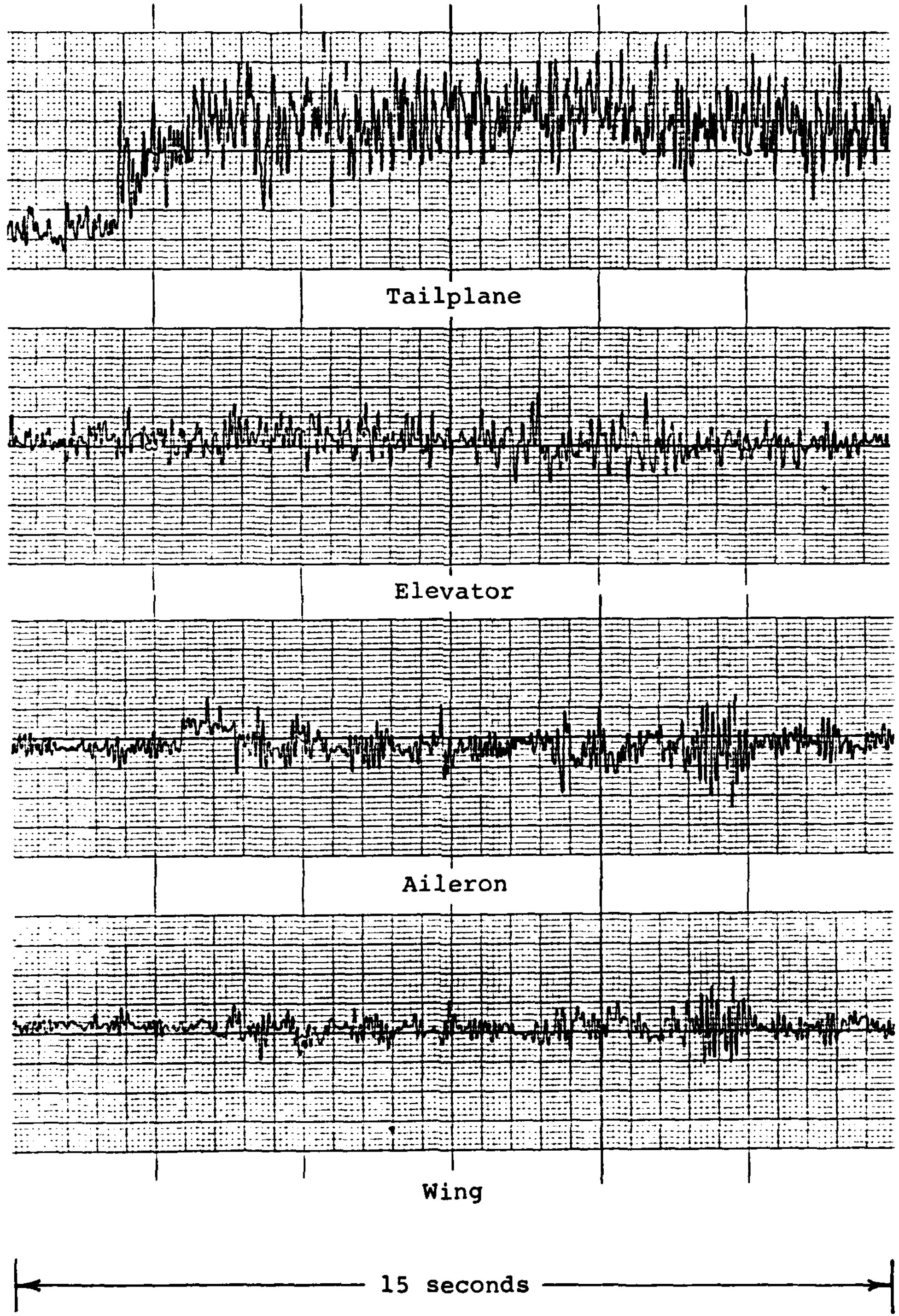


FIG. 20 RESPONSE TO STICK RAPS AT 150 KNOTS



162 knots

FIG. 21 RESPONSE TO STICK RAPS AT 162 KNOTS

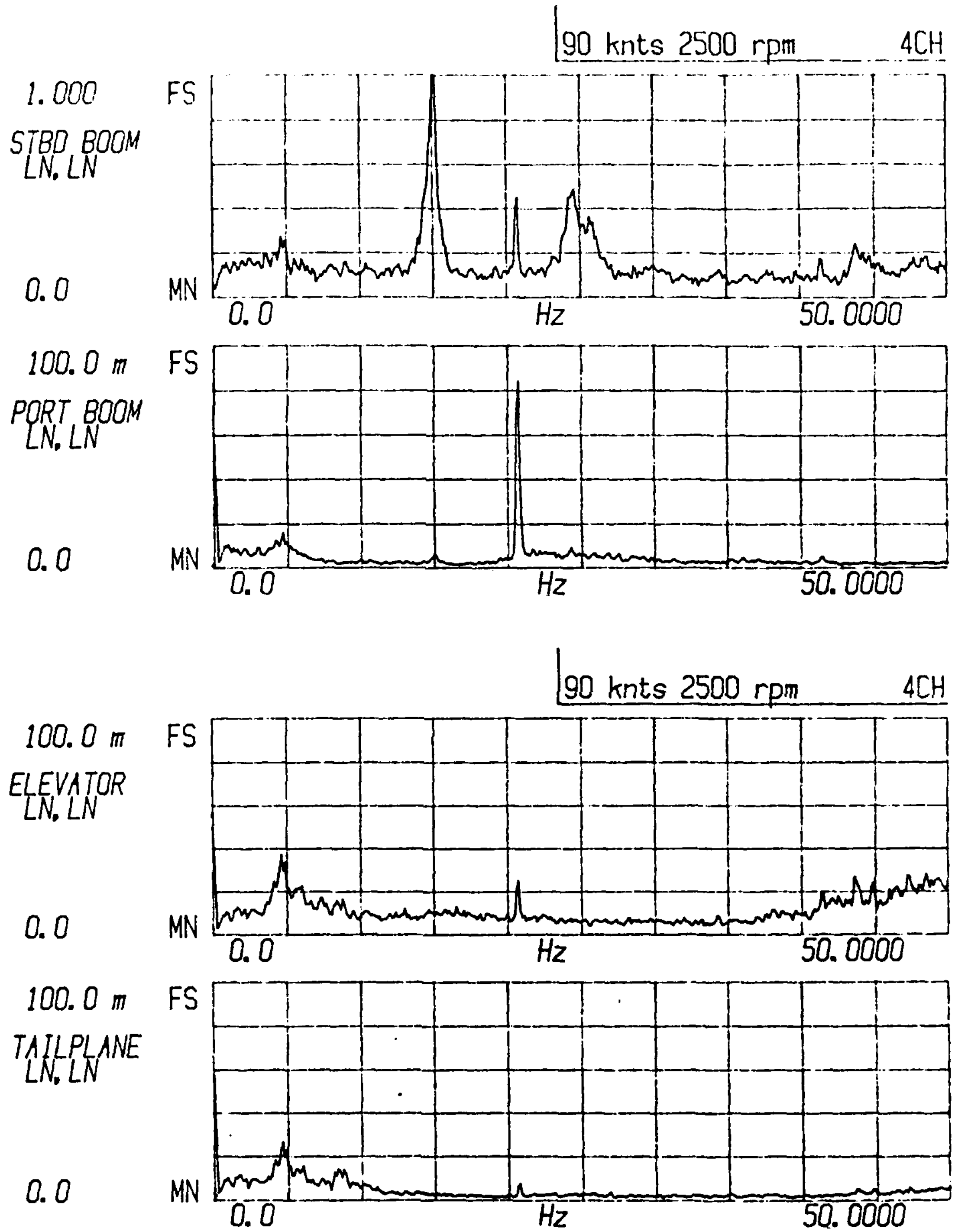


FIG. 22 RESPONSE TO TURBULENCE AT 90 KNOTS

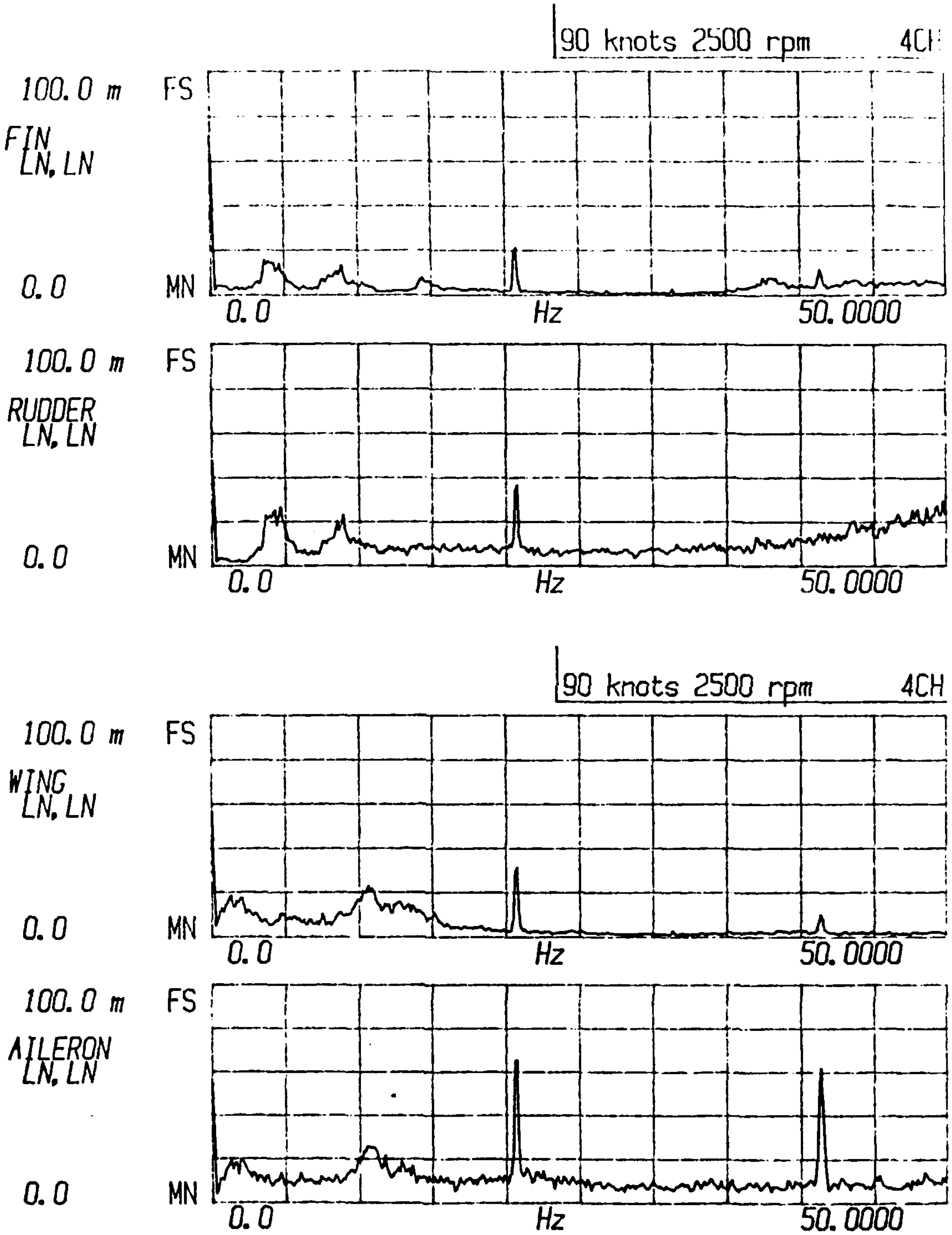


FIG. 23 RESPONSE TO TURBULENCE AT 90 KNOTS

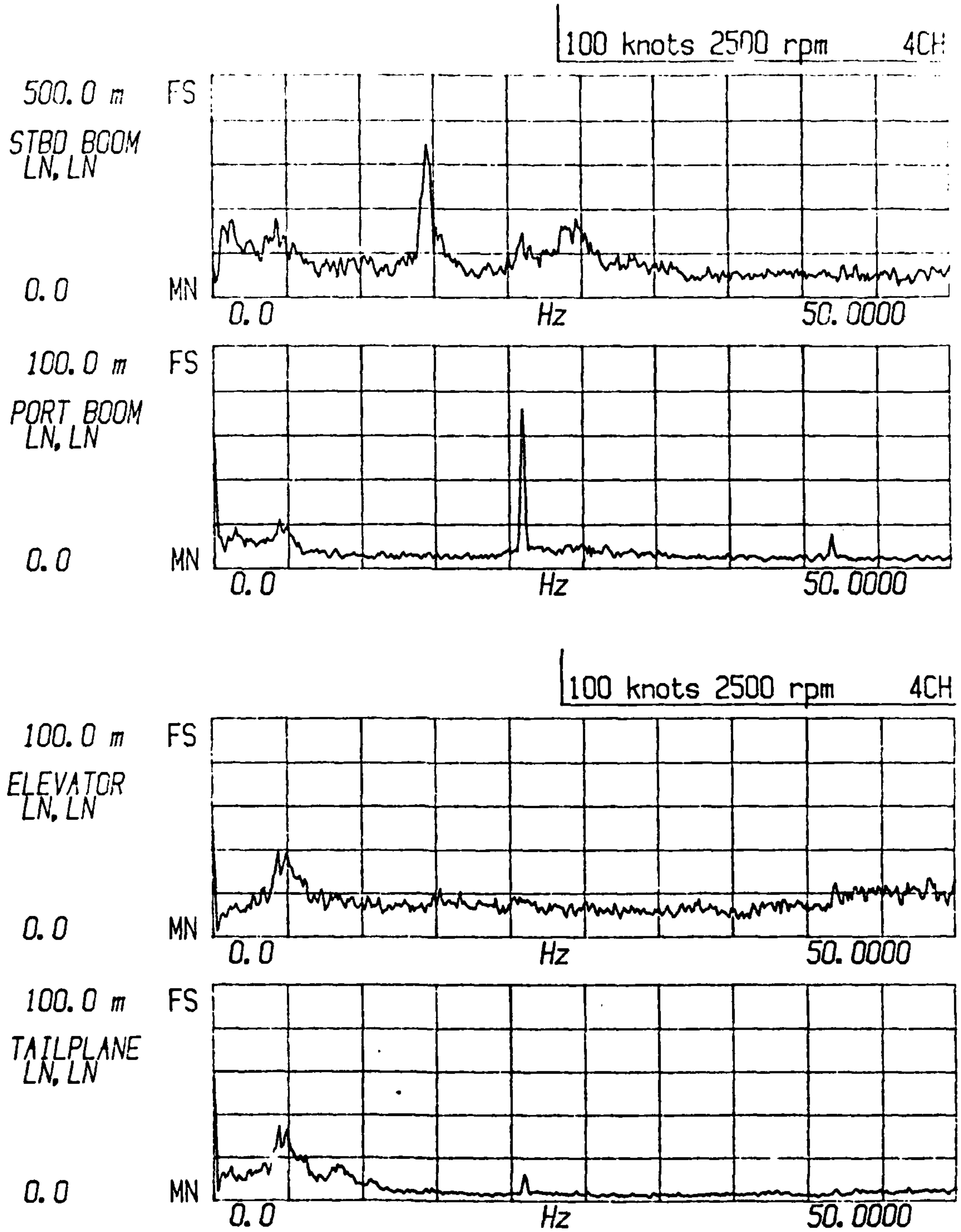


FIG. 24 RESPONSE TO TURBULENCE AT 100 KNOTS

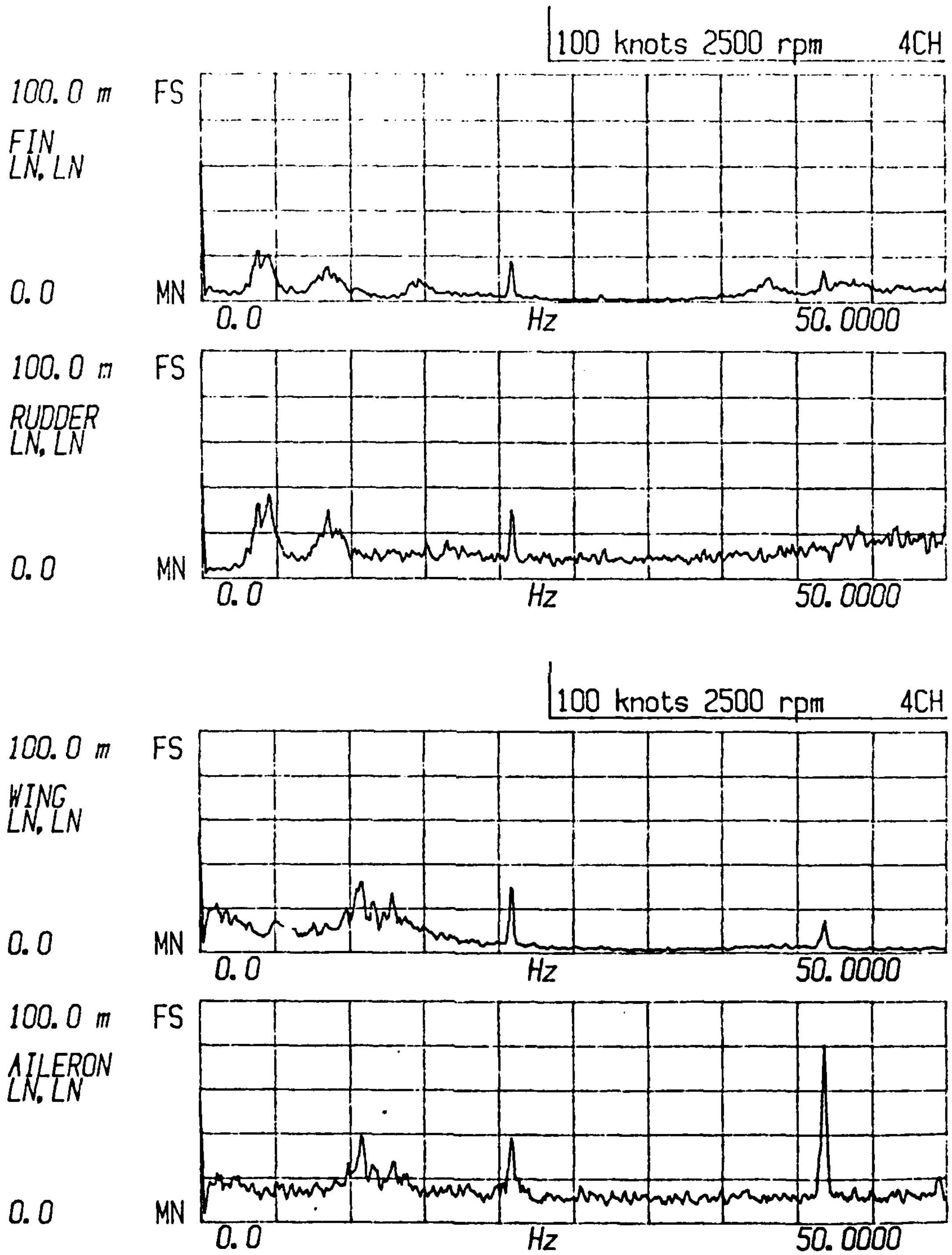


FIG. 25 RESPONSE TO TURBULENCE AT 100 KNOTS

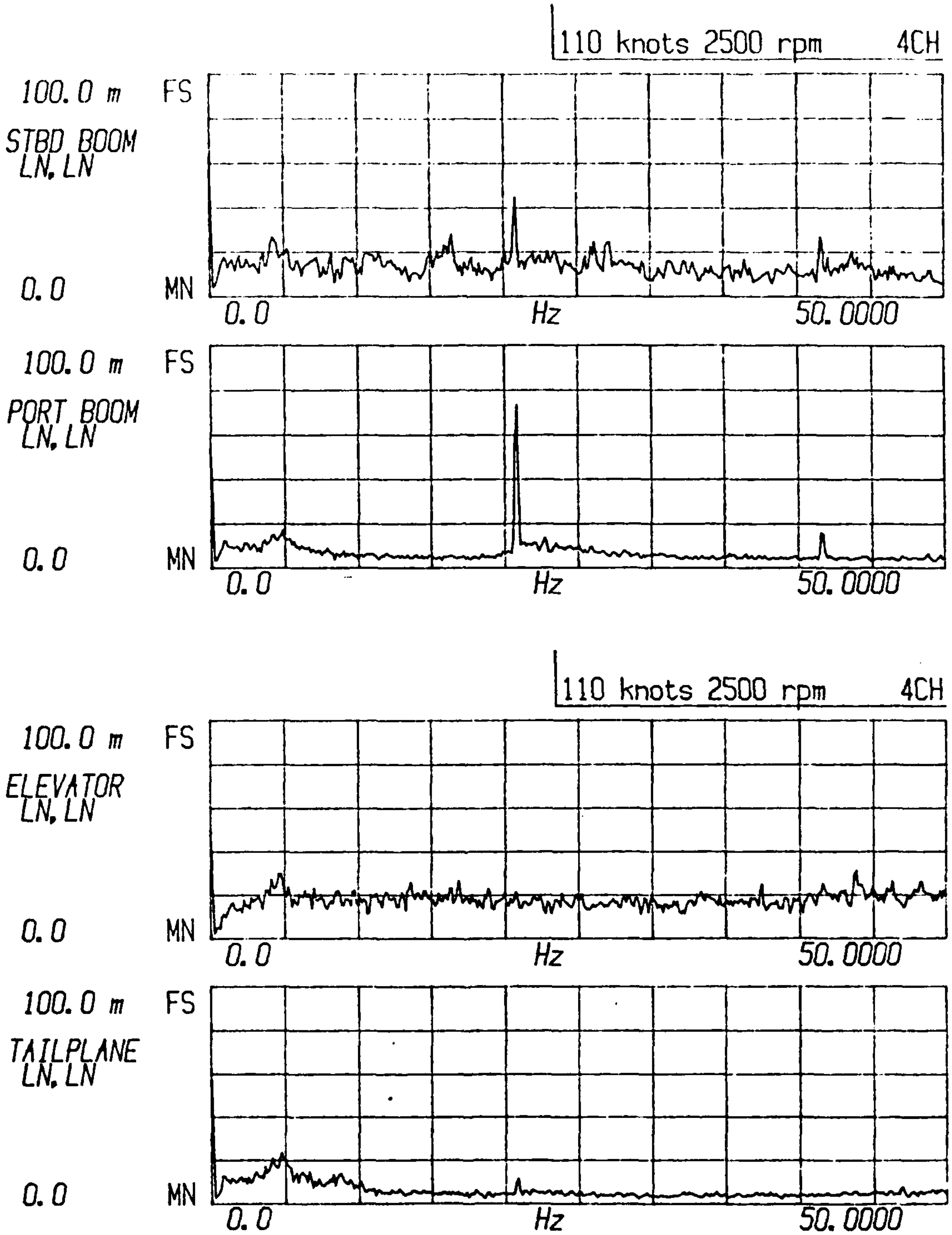


FIG. 26 RESPONSE TO TURBULENCE AT 110 KNOTS

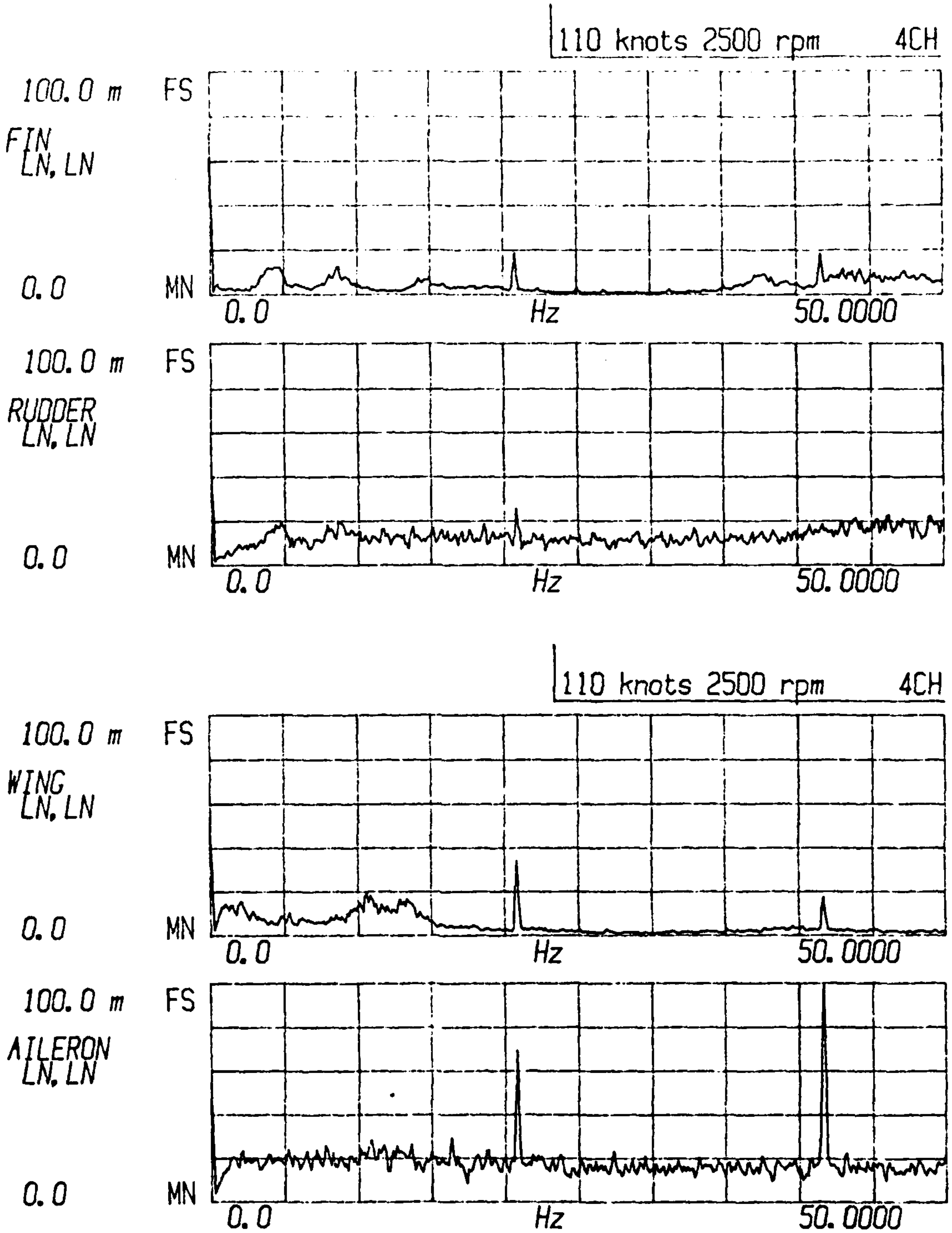


FIG. 27 RESPONSE TO TURBULENCE AT 110 KNOTS

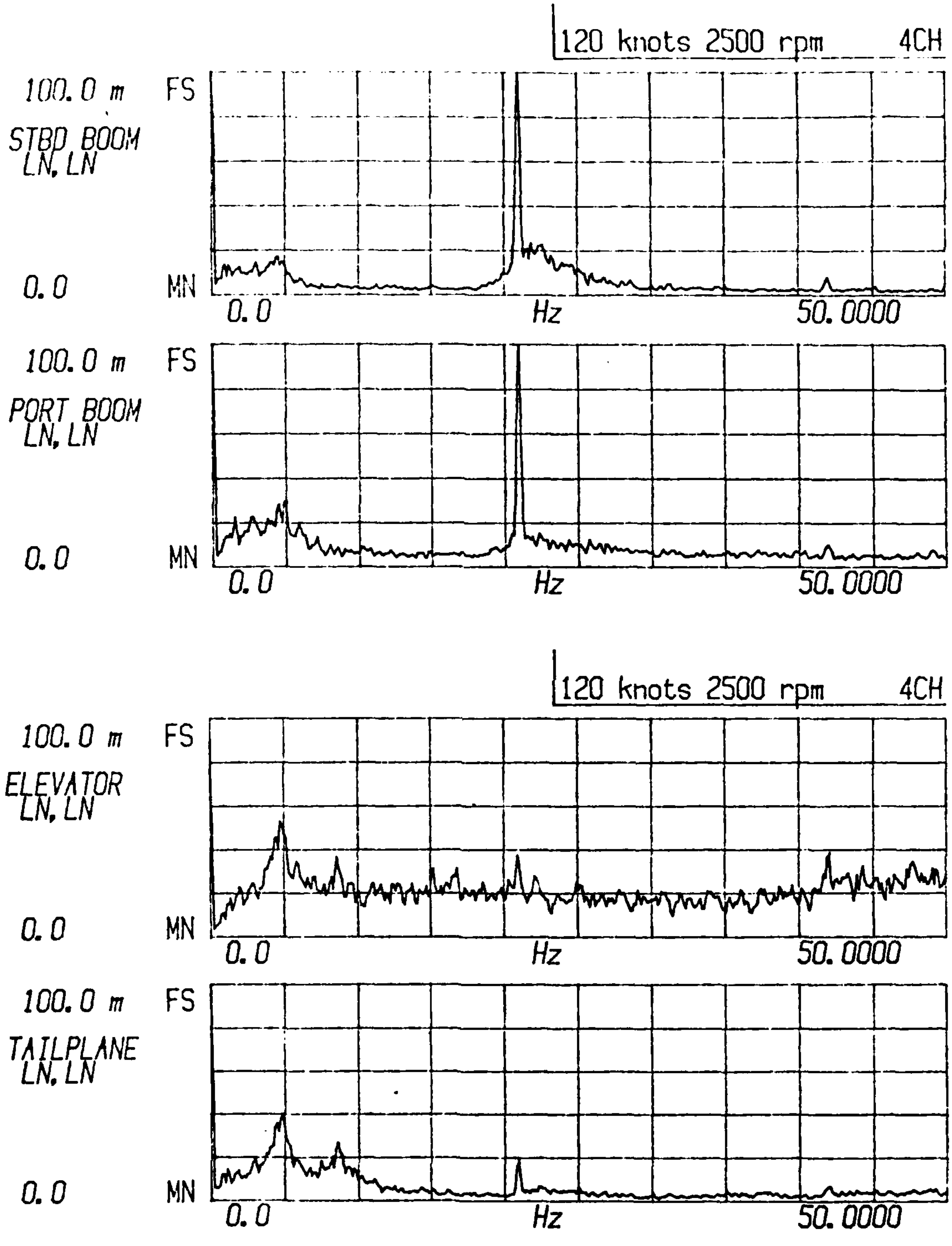


FIG. 28 RESPONSE TO TURBULENCE AT 120 KNOTS

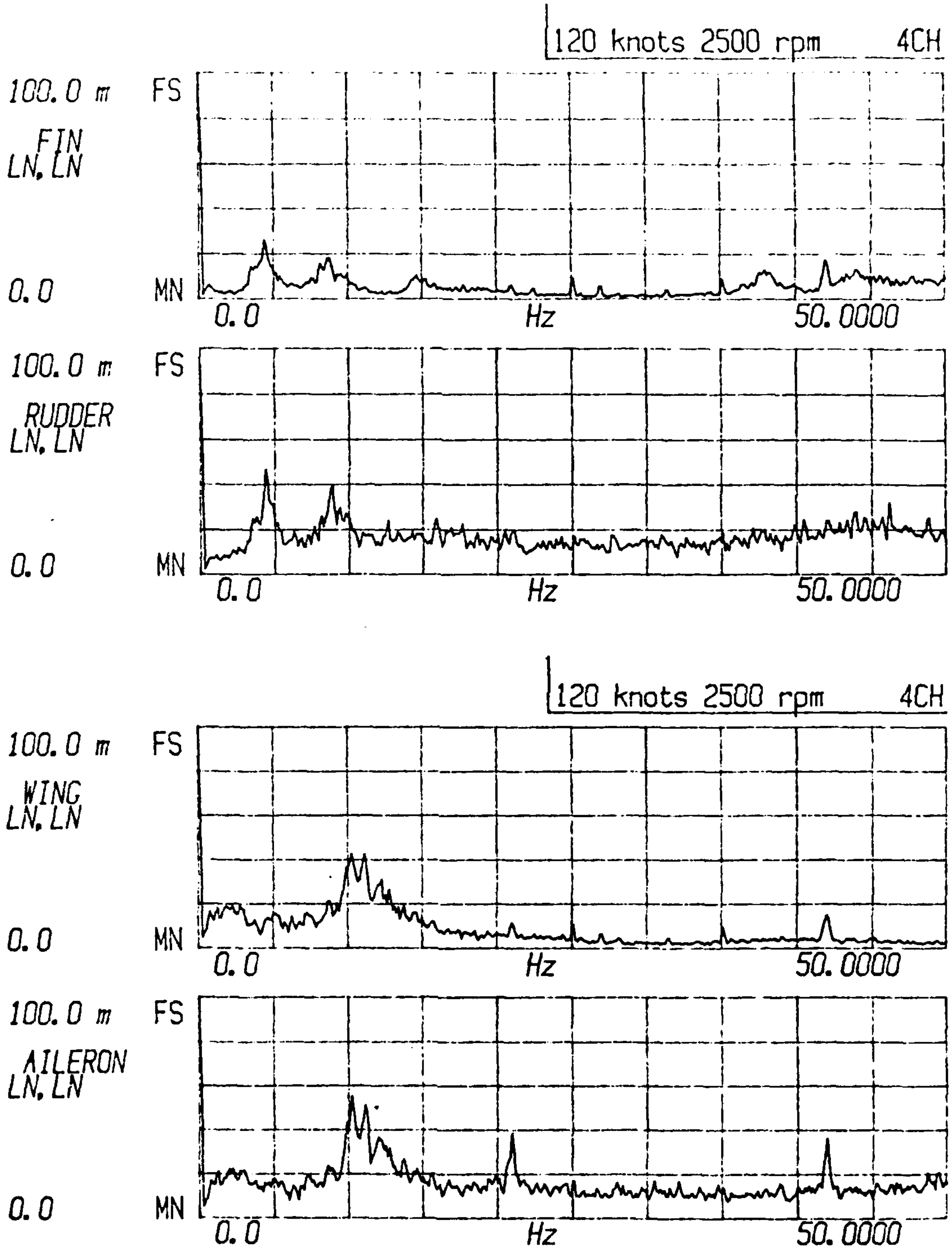


FIG. 29 RESPONSE TO TURBULENCE AT 120 KNOTS

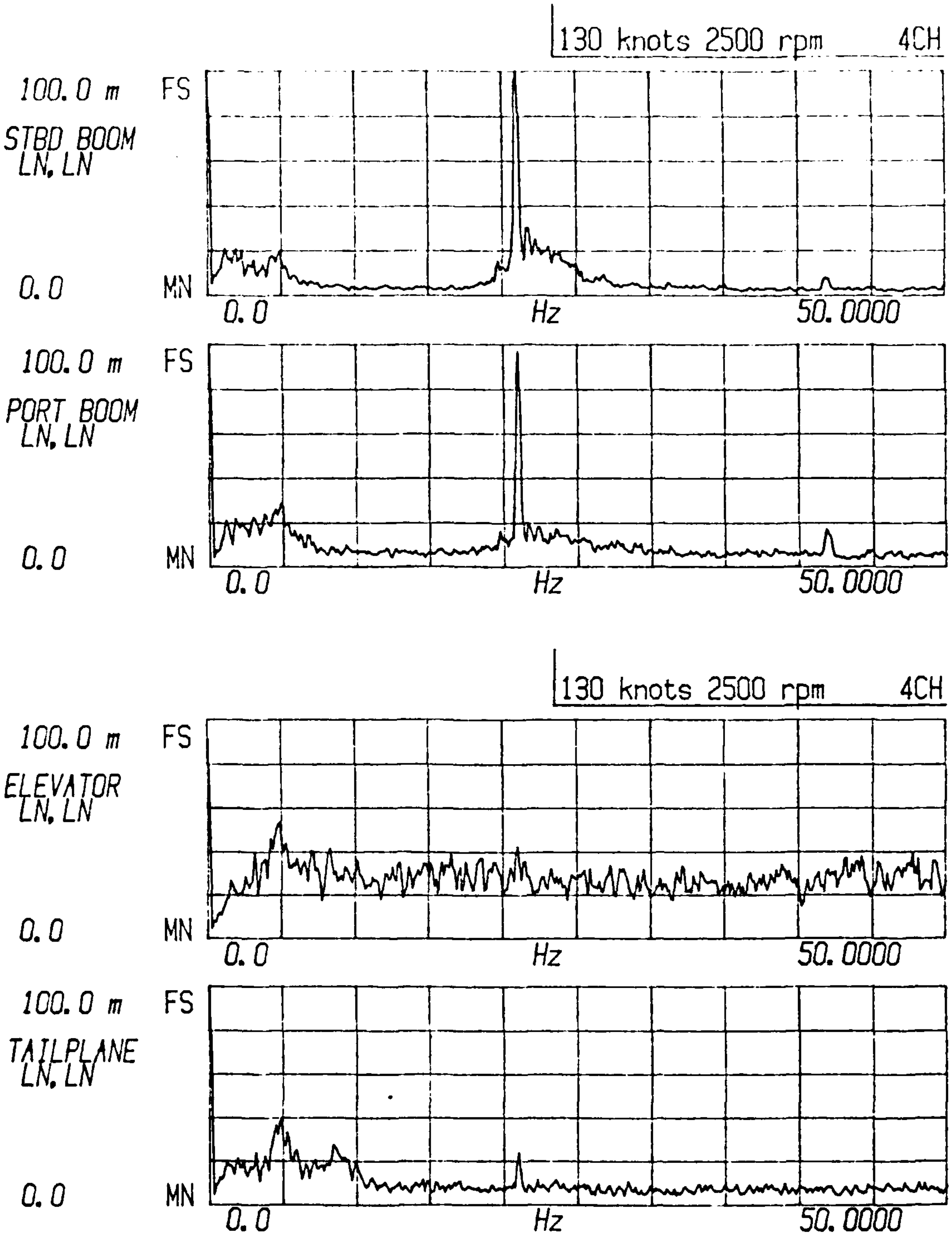


FIG. 30 RESPONSE TO TURBULENCE AT 130 KNOTS

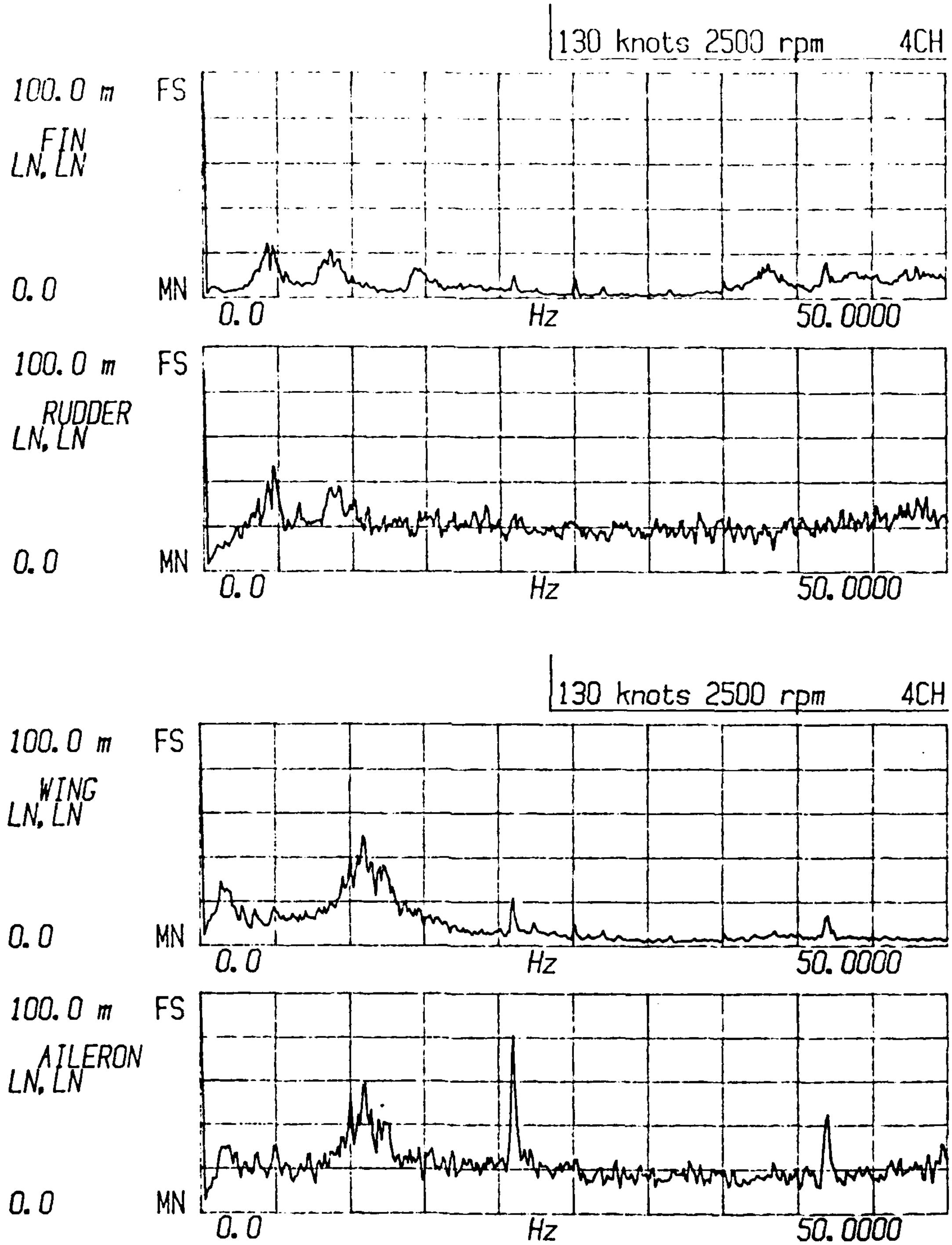


FIG. 31 RESPONSE TO TURBULENCE AT 130 KNOTS

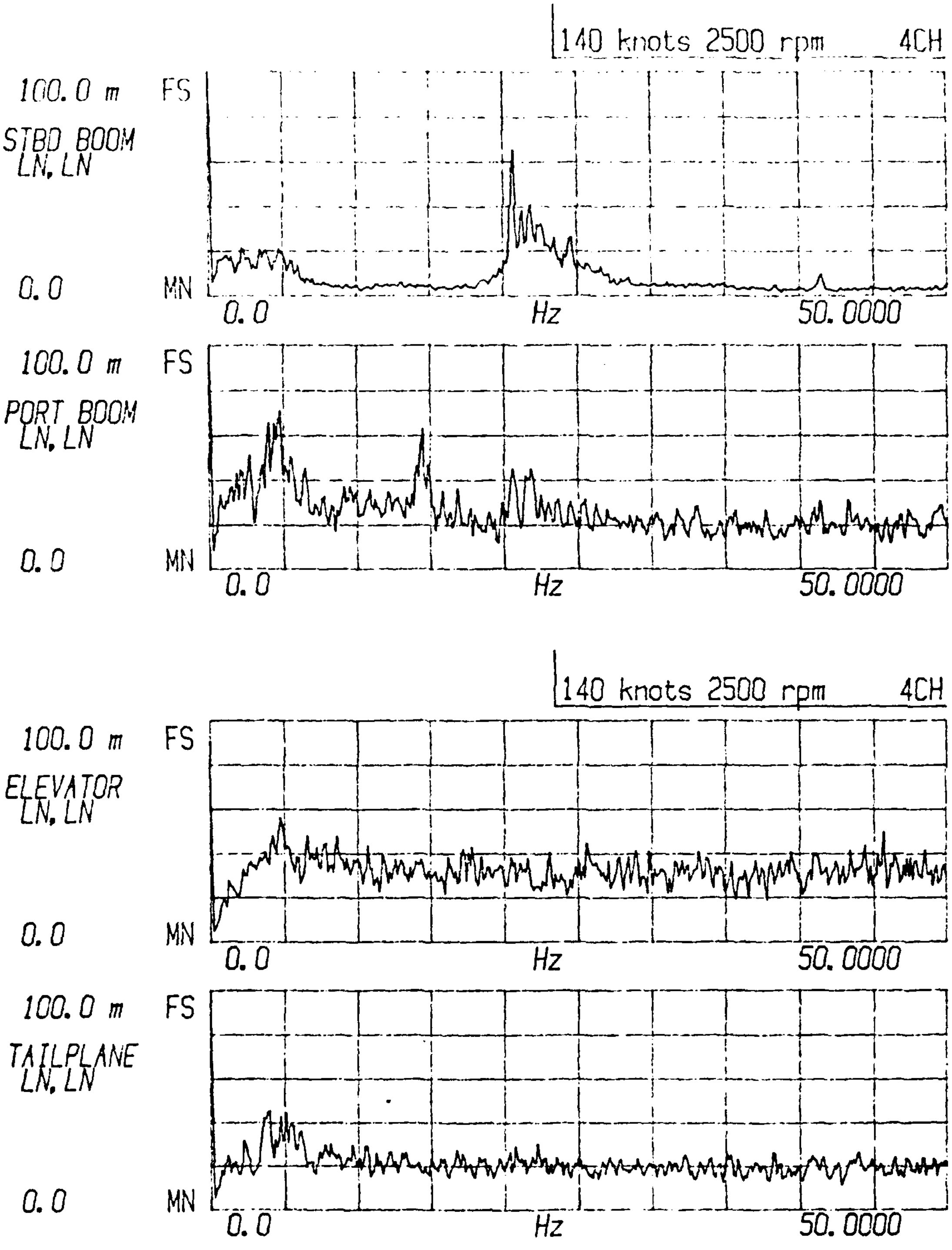


FIG. 32 RESPONSE TO TURBULENCE AT 140 KNOTS

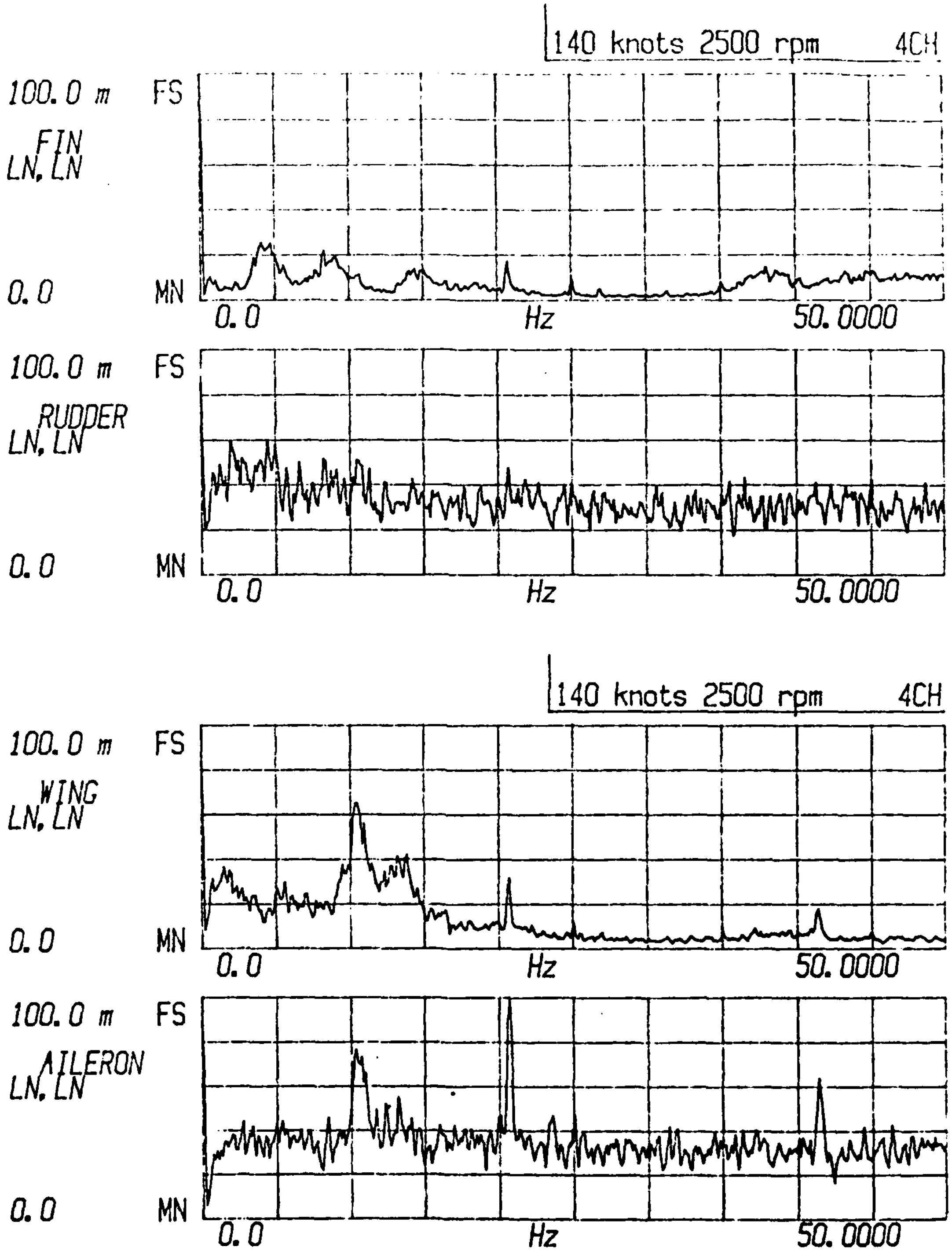
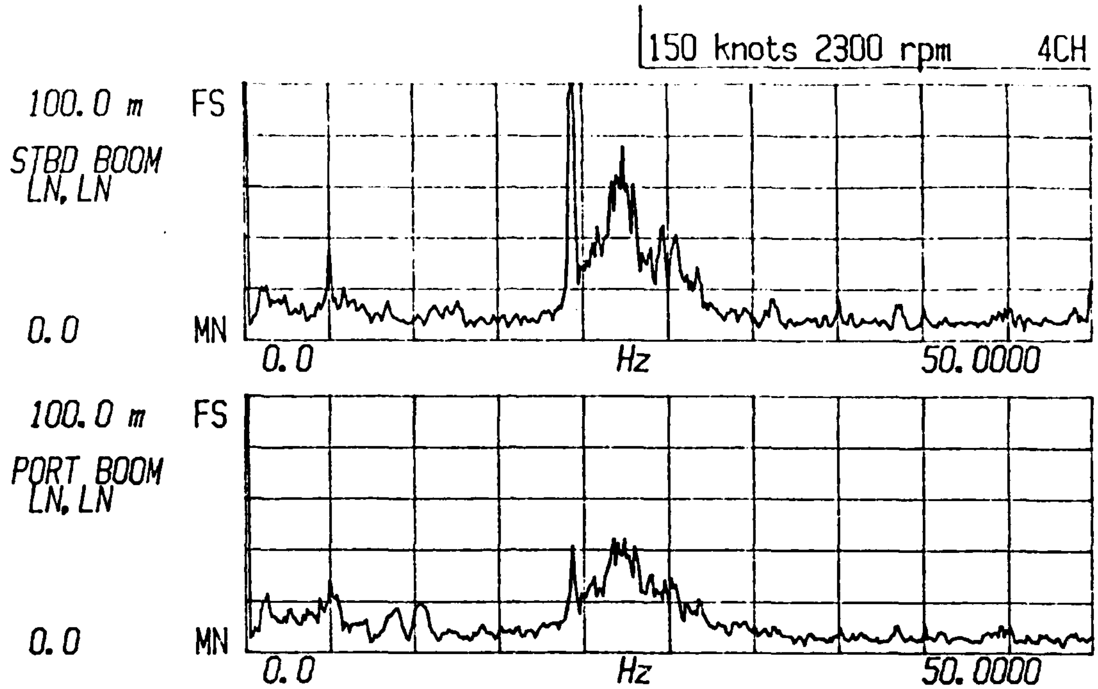


FIG. 33 RESPONSE TO TURBULENCE AT 140 KNOTS



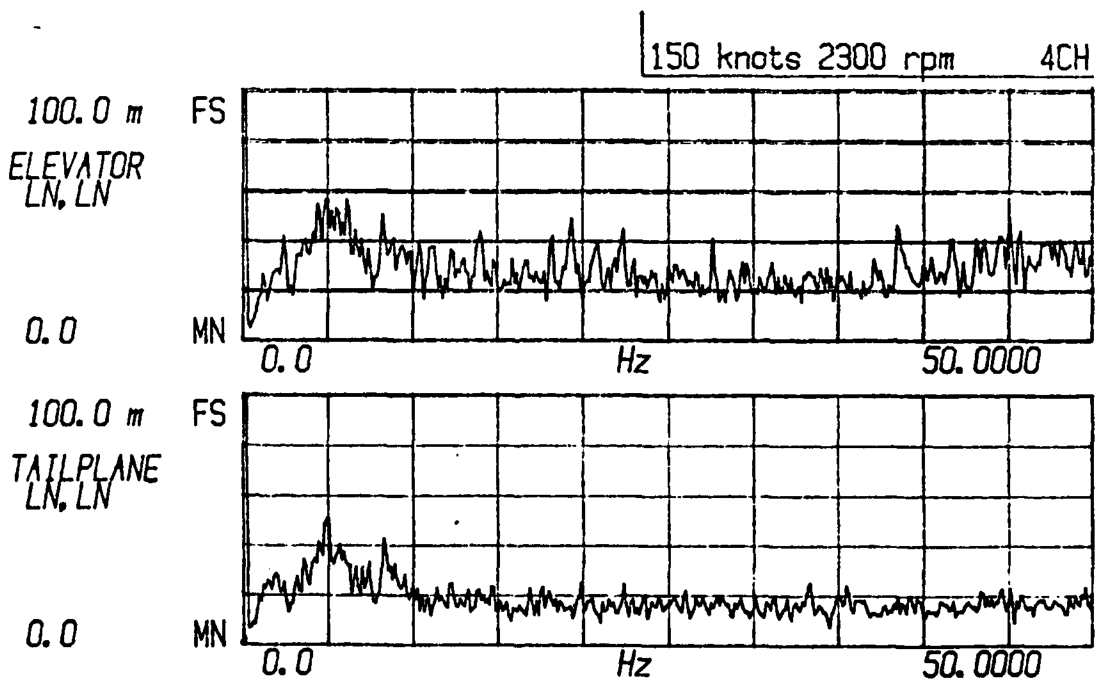


FIG. 34 RESPONSE TO TURBULENCE AT 150 KNOTS

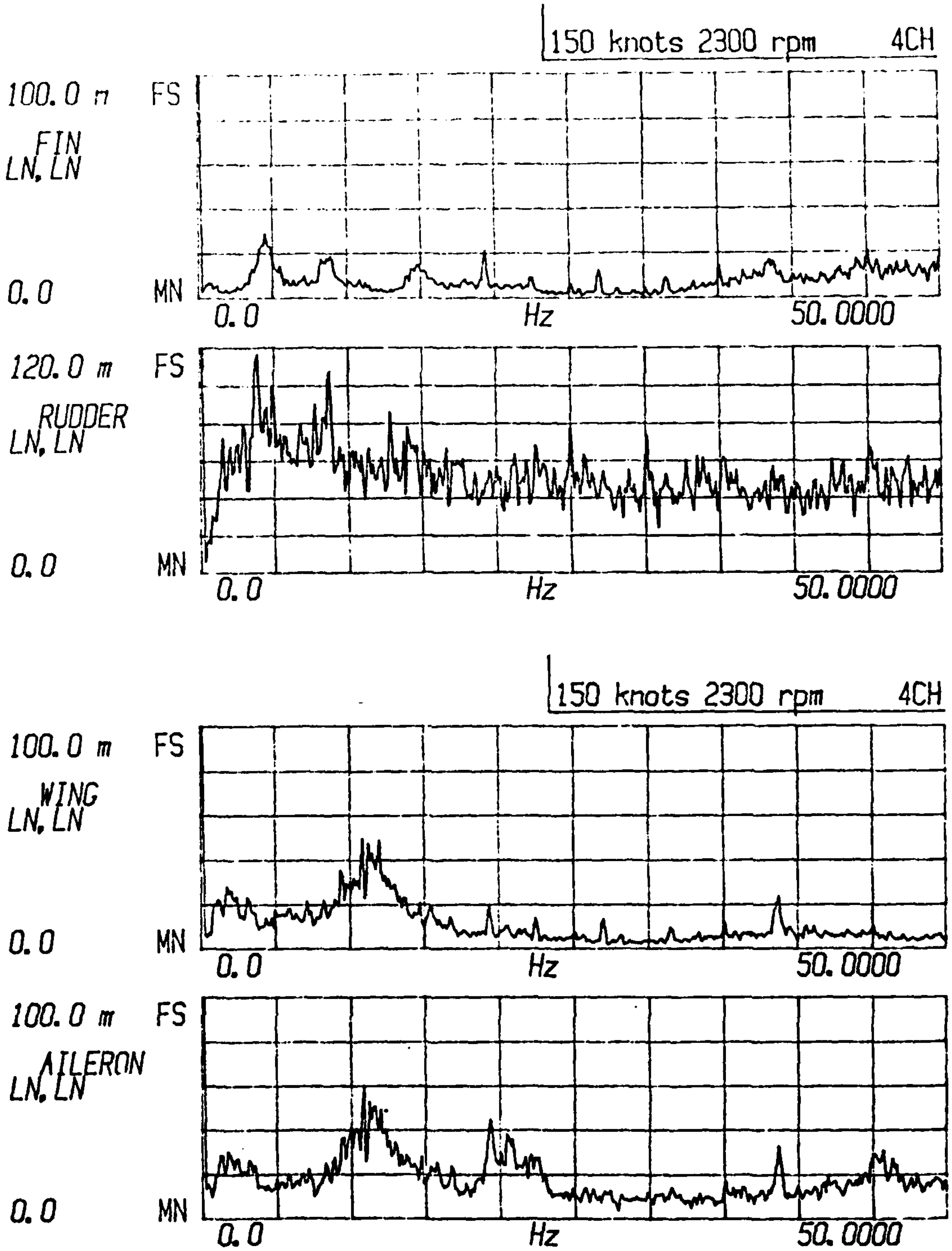
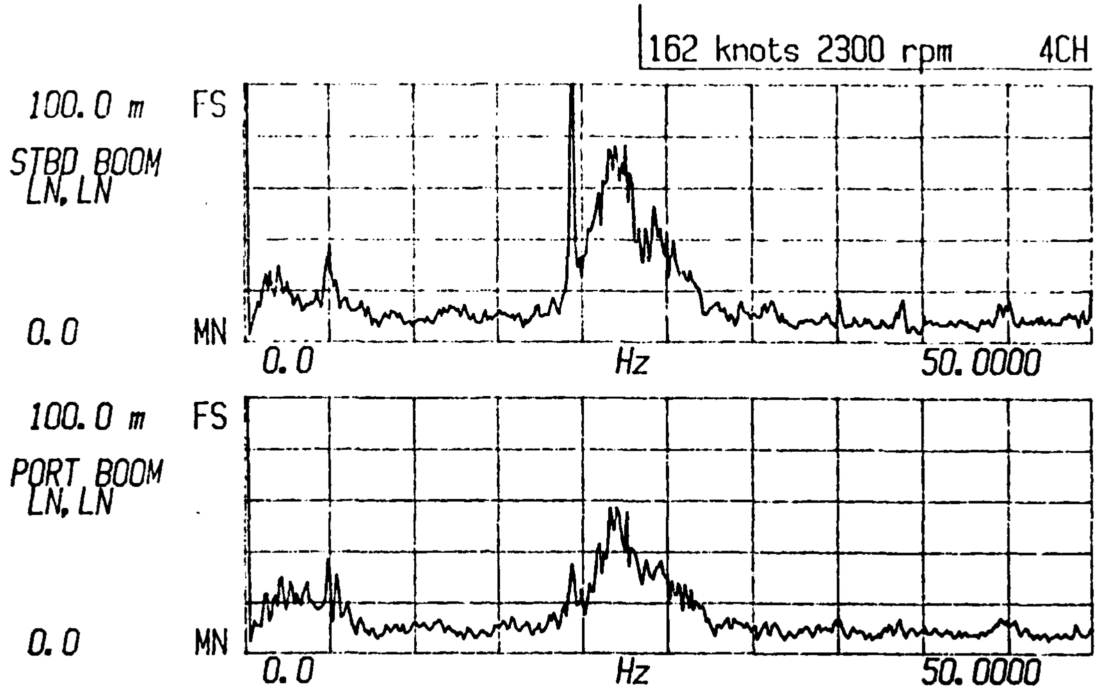


FIG. 35 RESPONSE TO TURBULENCE AT 150 KNOTS



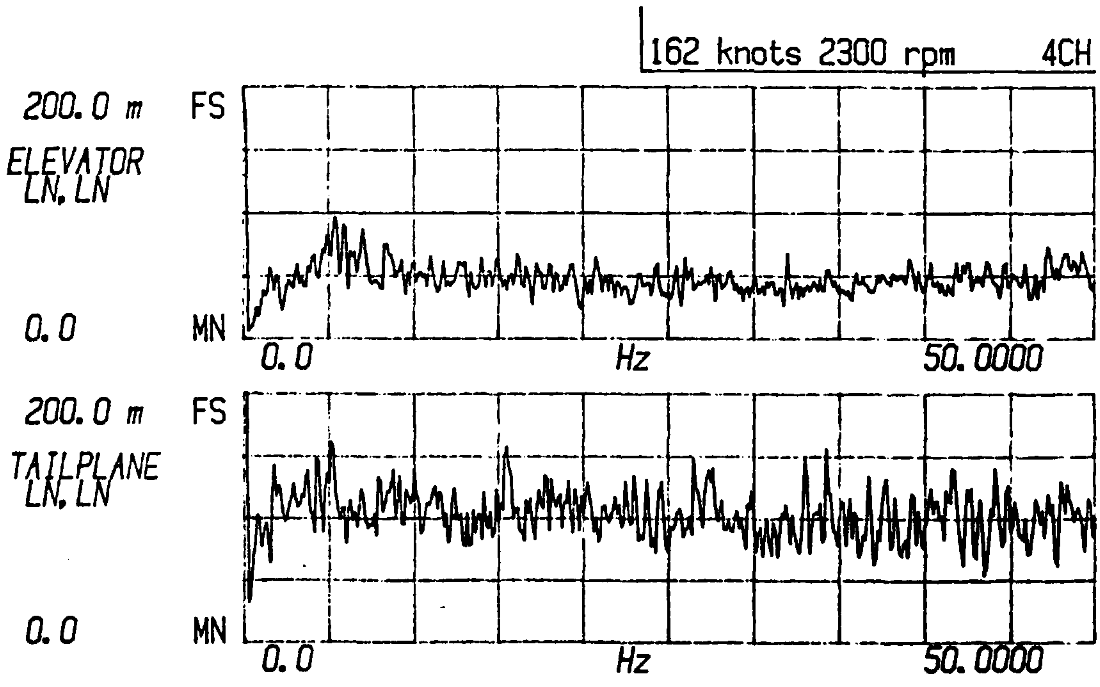


FIG. 36 RESPONSE TO TURBULENCE AT 162 KNOTS

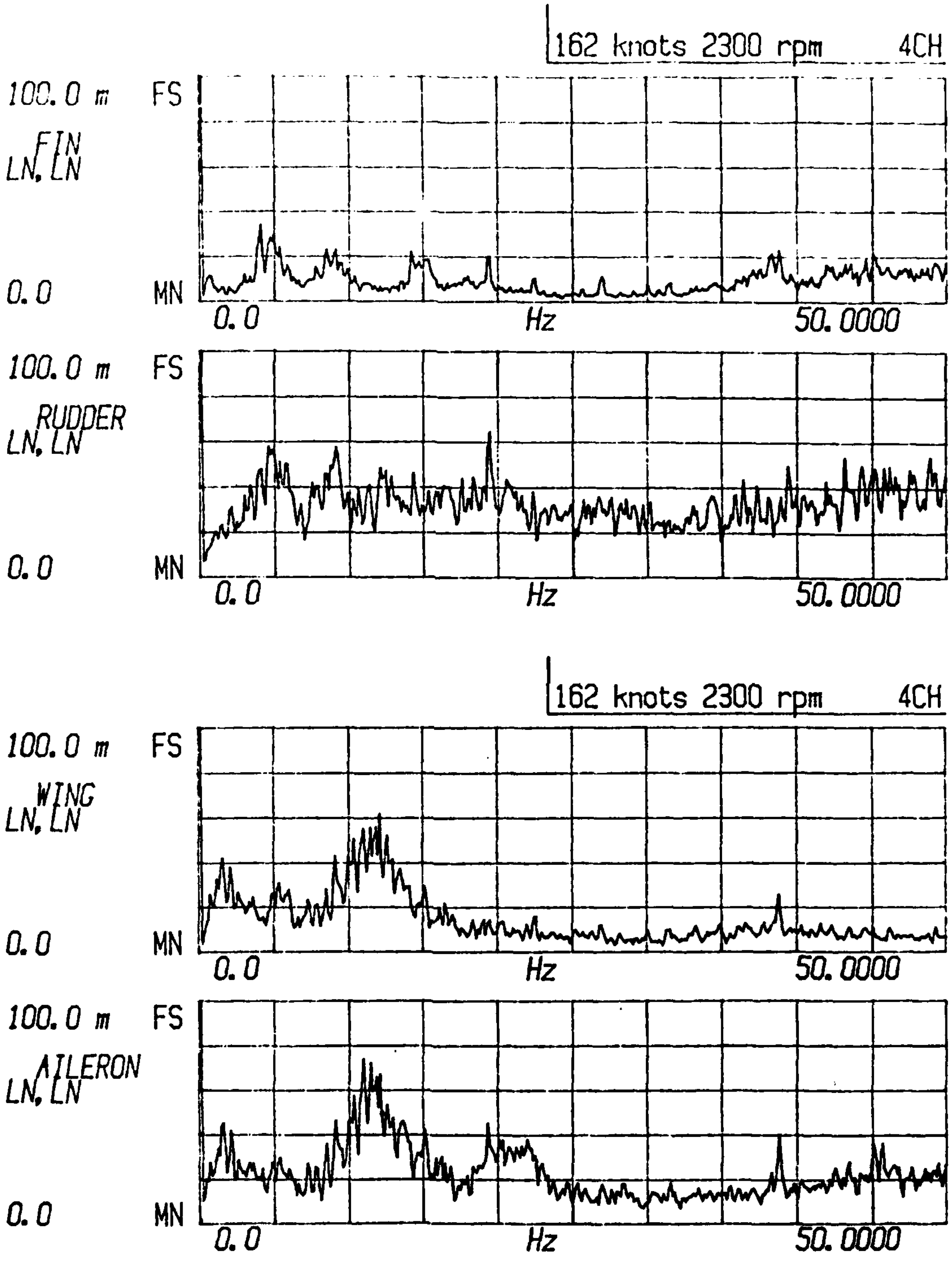


FIG. 37 RESPONSE TO TURBULENCE AT 162 KNOTS

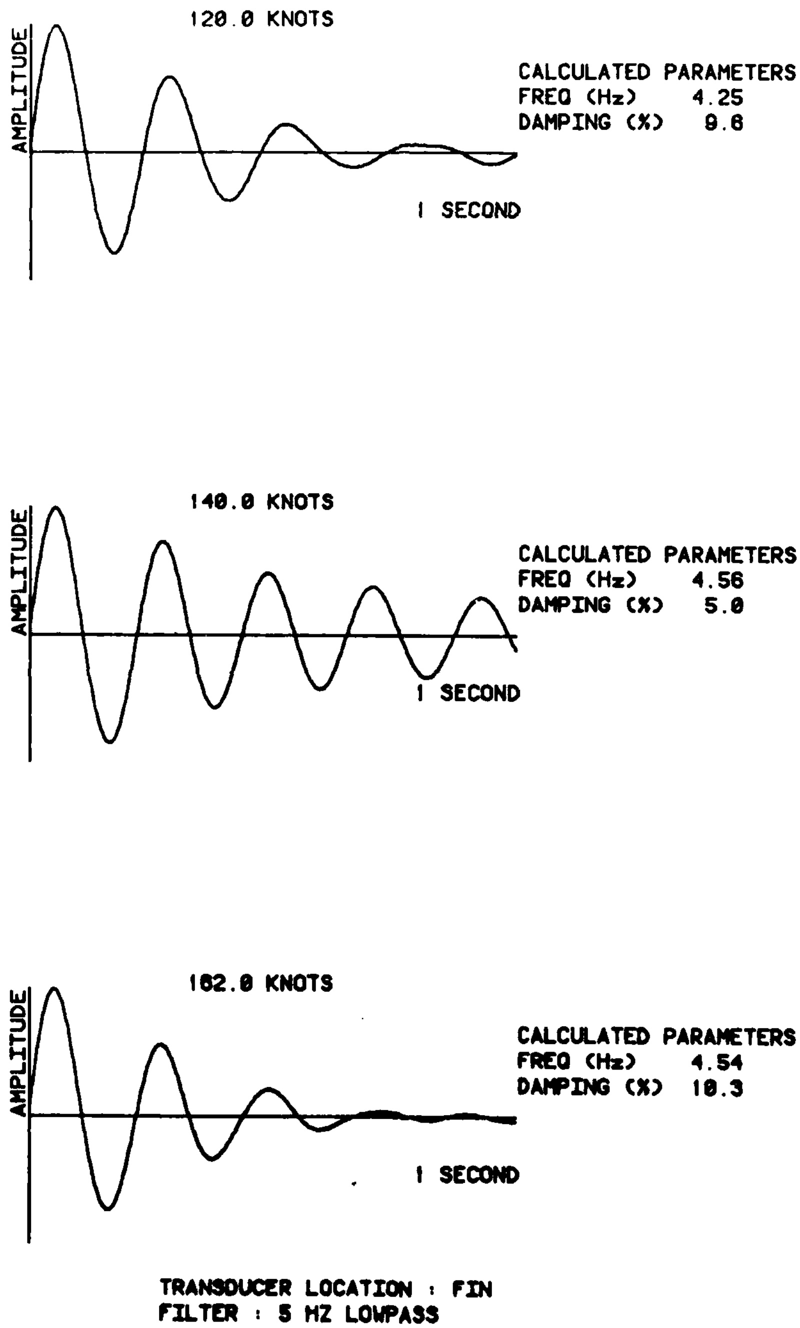


FIG. 38 RANDOM DECREMENT ANALYSIS

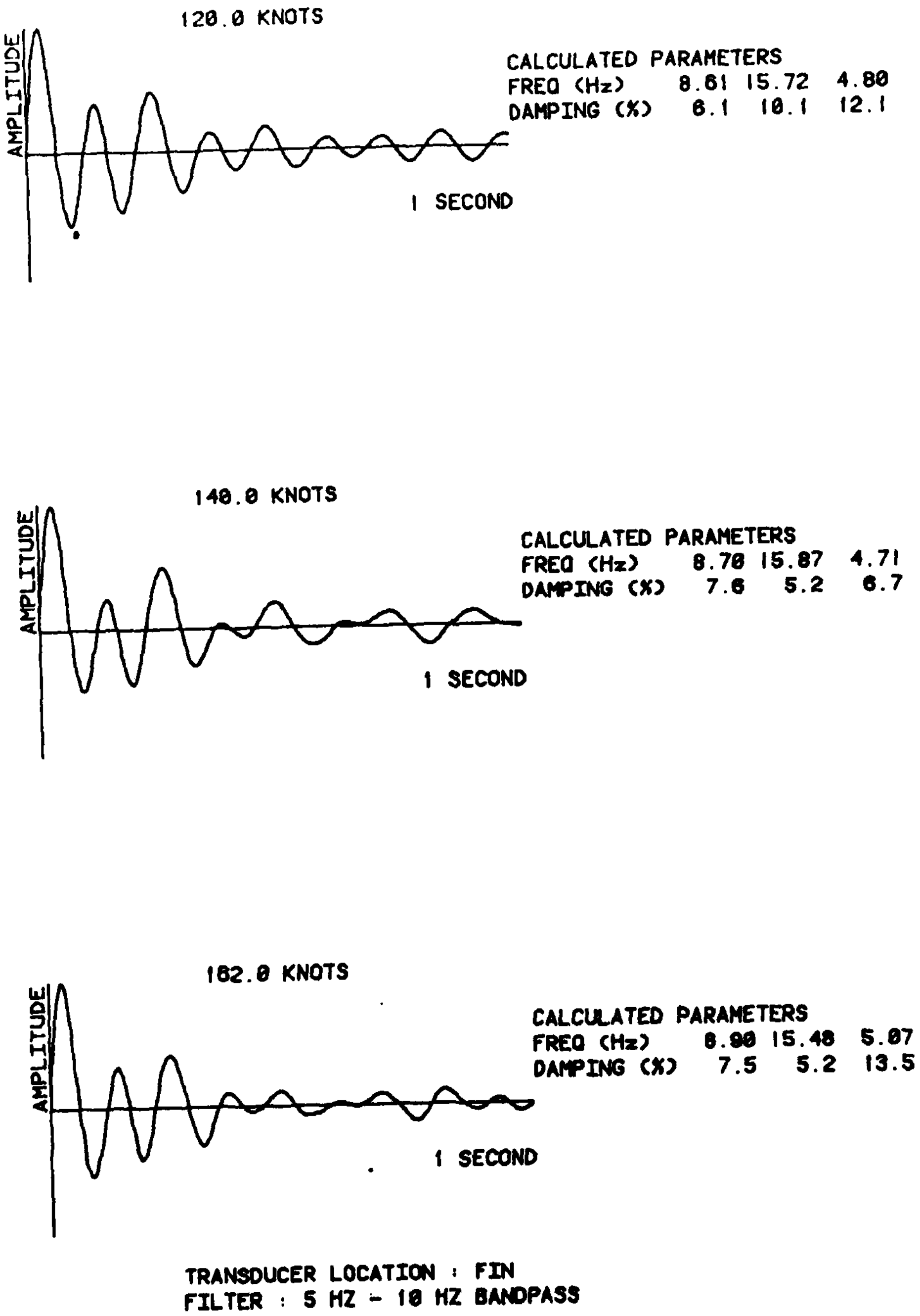


FIG. 39 RANDOM DECREMENT ANALYSIS

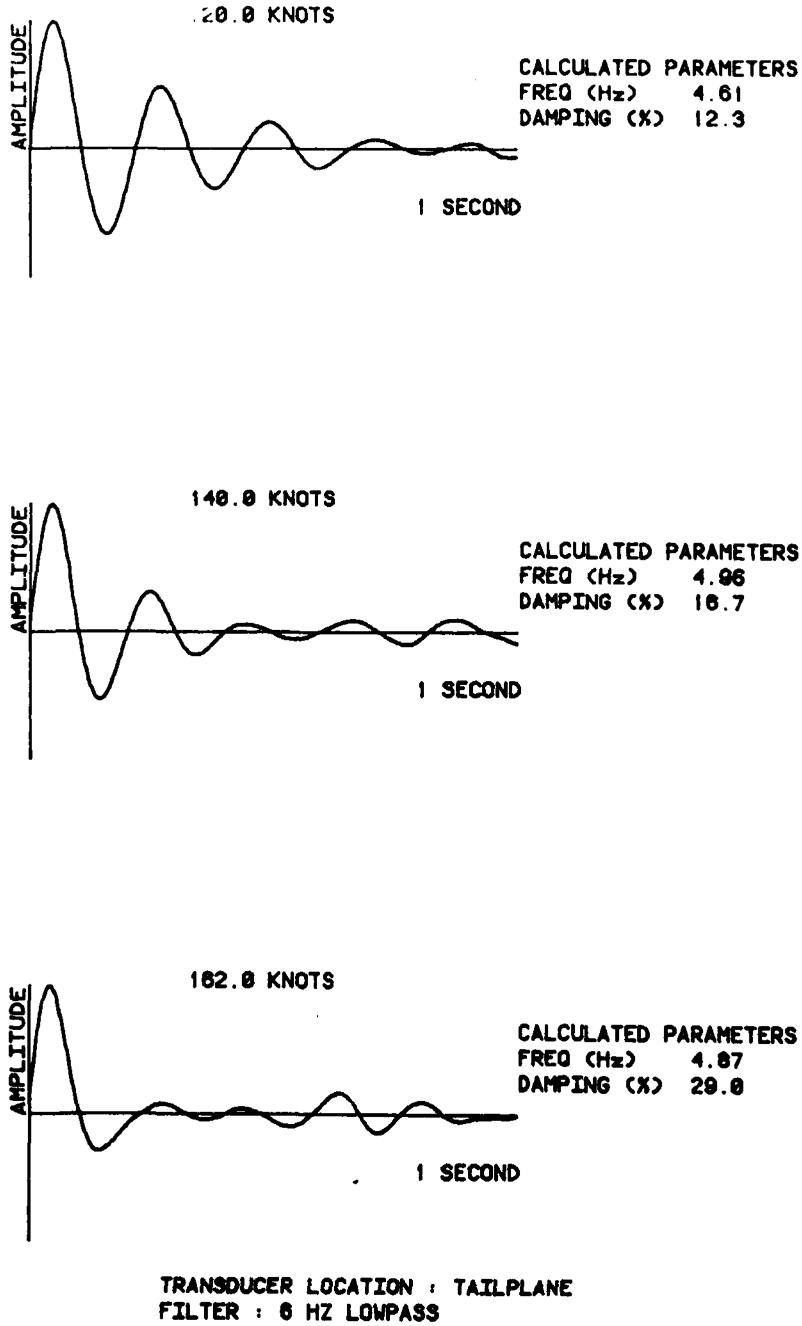


FIG. 40 RANDOM DECREMENT ANALYSIS

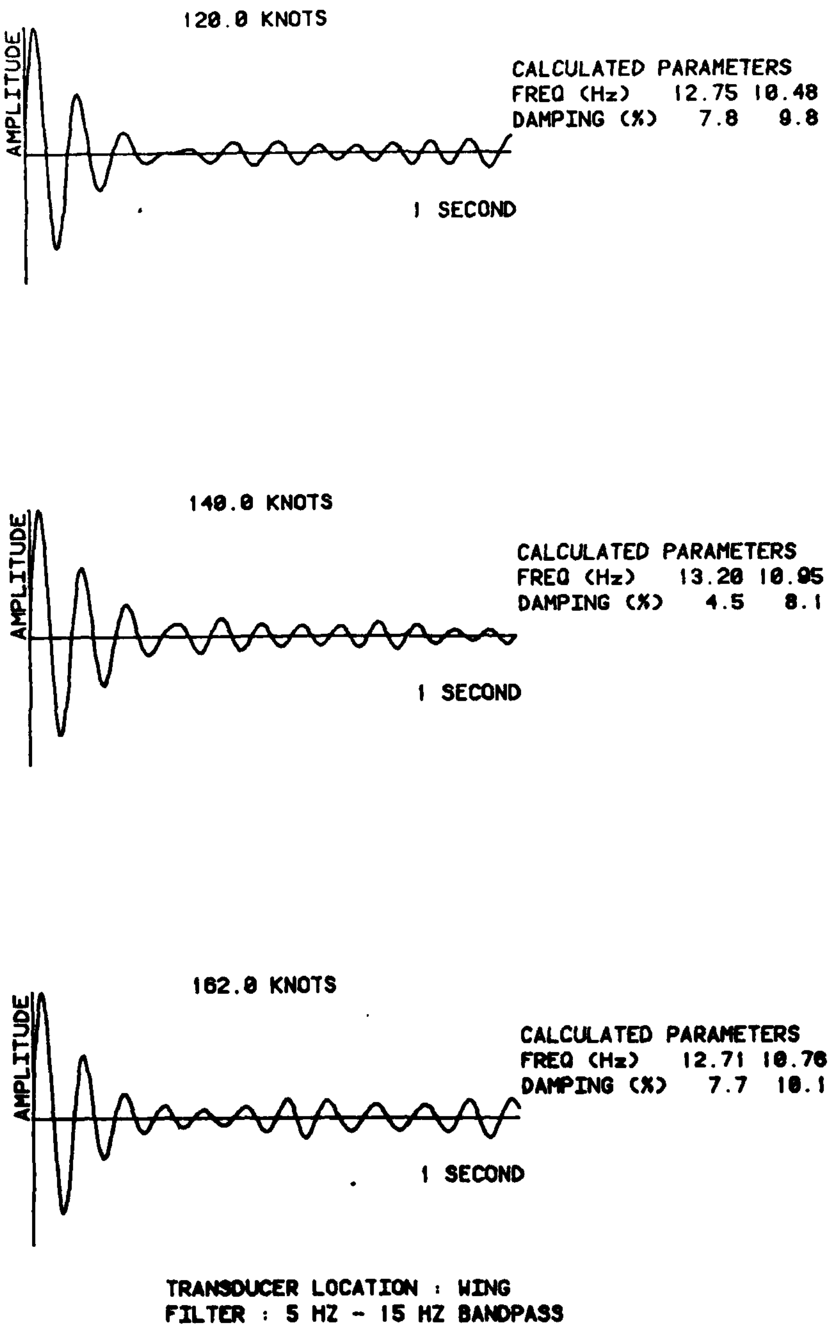


FIG. 41 RANDOM DECREMENT ANALYSIS

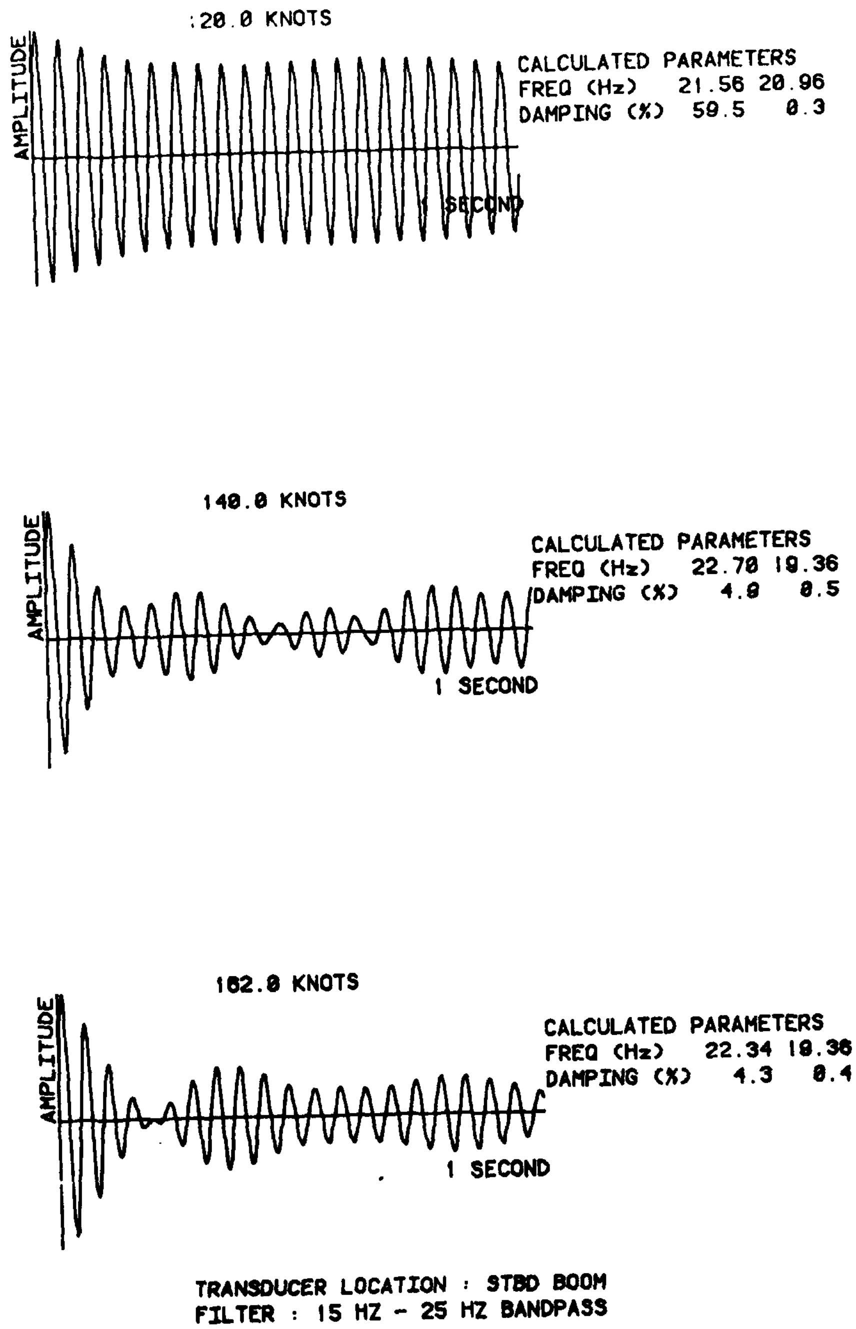


FIG. 42 RANDOM DECREMENT ANALYSIS

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Vibration tests;		

16. Abstract

Cont Gp 1 A ground resonance test and subsequent flight tests were ~~have been~~ conducted on a Transavia T-400 Skyfarmer. The natural modes and frequencies of vibration were measured in the ground tests, and monitored during flight tests in which attempts were made to induce flutter. The results of these tests are presented.

Keywords: -

PF 65

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